SECTION 308
TASK XIV
SEPTIC SYSTEMS

FIELD EVALUATION OF FOUR ONSITE DISPOSAL SYSTEMS AND THEIR IMPACTS TO SHALLOW GROUNDWATER IN THE COASTAL ZONE OF SOUTH CAROLINA

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INTRODUCTION

South Carolina's coastal zone is rich in both its variety and abundance of natural resources. Although the state's coastline is only 187 miles long, its numerous estuaries, bays, rivers and creeks combine to create an actual shoreline nearly 3,000 miles in length. Alongside the maze of estuaries and creeks flourish thousands of acres of marsh, constituting some of the richest, most productive areas on earth - areas vital to the existence of the majority of marine life found in both offshore and inshore waters of our coast. Estuaries play a vital role as breeding and/or nursery grounds for commercially important species such as shrimp, crabs, oysters, clams and numerous kinds of fish (S.C. Coastal Council, 1993).

The estuarine ecosystem is delicately balanced and extremely vulnerable to the external stresses imposed on it by man. The decline in oyster production is one example of this. Since the turn of the century, South Carolina oyster production has decreased by more than 90% while nationwide production has decreased by 76% (Scott, 1996). Although there are many contributing factors, high fecal coliform bacteria levels are often cited as a reason for closing oyster beds to harvesting. The potential sources of fecal coliform bacteria include septic systems, sewer system overflows, pet waste, wildlife fecal waste and fecal waste from mismanaged livestock operations. These sources can also contribute excessive nutrient loads which can result in eutrophication of surface waters.

In developed coastal areas, septic systems are often blamed for polluting surface waters with fecal coliform bacteria. This blame may be justified for older, unmaintained systems, as many were permitted under the pre-1986 septic system regulations. These earlier regulations relied on less proven methods of site evaluation (e.g., the 'perc' test) and included fewer options for system design modifications. In addition, older systems that have not been properly maintained are more likely to fail. Even properly functioning systems can leach excessive nitrates into groundwater.

Today, many areas of our coastal zone are being developed at a rapid pace and septic systems are still relied upon for providing wastewater treatment. Although the State's onsite program utilizes more reliable site evaluation techniques (e.g., soil redoxymorphic features) to determine seasonal high water table, and the current regulations allow for flexibility in system design, blame is still being placed on septic systems for polluting surface waters.

Septic systems that are failing on the surface of the ground are fairly easy to detect using obvious signs such as effluent on the ground, slowly draining pipes or sewage backing up into the house, and lush green grass growing over the trench lines. Septic systems that are failing below the surface of the ground are much more difficult to detect without the use of groundwater monitoring or dye tracer studies. These subsurface failures may be impacting groundwater and surface waters that are closely hydrologically connected.

The nature of our coast is such that the potential is great for polluted groundwater to impact shellfish grounds and other sensitive coastal resources that are closely hydrologically connected. In addition, South Carolina has been accused of having some of the weakest onsite regulations in the region, particularly with regard to separation distance between the trench bottom and the seasonal high water table (SHWT). Whereas S.C. requires a minimum of six inches of separation, the majority of coastal states require a minimum separation distance of two feet and some states require as much as four to five feet of separation. There is a large body of research from other states that supports the greater separation distances (Anderson *et al.*, 1993; Cogger *et al.,* 1988; Duncan *et al.*, 1994).

South Carolina's standards for individual waste disposal systems (R.61-56) became effective in June 1986. Several DHEC or DHEC-sponsored studies on coastal zone septic systems have been conducted prior to and subsequent to the adoption of R.61-56. A DHEC study on the hydrogeology of the shallow aquifers of the lower Coastal Plain of South Carolina and the impacts of land disposal sites on the shallow groundwater found that "the highest degree of groundwater contamination was found near tile field systems that were located in very permeable sediments with a shallow water table." In addition, it stated that "the greatest volume of contaminants entering the groundwater is from tile field effluent contributed by subdivisions and trailer parks" (SCDHEC, 1980).

A collaborative research project between DHEC and the University of South Carolina was initiated in the late 1980's on numerous older, newer, and experimental systems all across the coastal zone. Due to reduced funding this project was not completed, and due to extremely dry weather it was not successful in evaluating the six-inch separation distance to SHWT. However, the project completion report identified several areas needing further study including: a) the effects of soil type and layering on groundwater mounding under septic systems; b) the separation distance (to SHWT) for all soil classes; and c) the residential absorption field standards to determine if drain fields are adequately sized (Meadows *et al.,* 1991).

An epidemiological and microbiological study related to the Meadows study was conducted by a USC doctoral student. This study concluded that coastal South Carolina residents who consume groundwater from shallow aquifers that are associated with a septic system (especially from wells which are less than 50 feet from a septic system), and who swim in estuarine water and consume estuarine shellfish in areas drained by septic tanks, are at increased risk of contracting bacterial enteritis. This study also noted the presence of bacterial serotypes in oysters that were similar to the ones present in drainfield wells, indicating the effect of contamination from drainfield runoff (El-Figi, 1990).

The objective of this study was to determine if septic systems installed under the current regulations (R. 61-56) performed adequately to protect shallow groundwater and closely hydrologically connected surface waters.

Background On Monitoring Parameters

Chloride

Chlorides are naturally occurring in both surface and ground waters and are also found in household and community wastewaters. Septic systems are ineffective at removing chloride from effluent. Chloride is, therefore, a useful tracer or indicator of septic tank effluent. It is considered a conservative indicator because it is a soluble anion and does not undergo biological or biochemical transformations in the septic tank, the soil or the groundwater. By comparing the chloride levels in an upgradient well with levels in downgradient wells, one can determine if the downgradient wells are detecting the effluent plume and then assess the transformations of other elements that may have occurred.

Nitrogen

Unlike chloride, the nitrogen in a septic tank system can undergo many changes. These changes are complex and for the sake of brevity will only be described in basic terms here. Total nitrogen levels in septic tank effluent range from 40-80 mg/l and occur primarily in the ammonium (about 75%) and organic (about 25%) forms. Anaerobic conditions in the septic tank are responsible for the conversion of organic nitrogen to ammonium and for the very low levels of nitrate in the tank. Septic tanks are ineffective at removing nitrogen from effluent.

Ammonium is the predominant form of nitrogen that enters the soil from the trenches. Ammonium can be adsorbed by the soil and if aerobic conditions are present it is converted to nitrate. As a soluble anion, nitrate is highly mobile and moves readily with groundwater, particularly within highly permeable subsurface materials. Under anaerobic conditions, both in the soil and in the groundwater, denitrification (transformation of nitrate to nitrogen gas) can occur which reduces the total nitrogen load to the subsurface environment.

Total Phosphorus

Total phosphorus levels in septic tank effluent typically range from 11-31 mg/l. The septic tank alone is not effective at reducing phosphorus levels, but the soil adsorption system is. Phosphorus undergoes many transformations in the soil environment which are highly dependent on soil characteristics. Movement of phosphorus from drainfields is usually insignificant and where it occurs, levels generally decrease rapidly with distance from the system.

Fecal Coliform Bacteria

The presence and amount of fecal coliform bacteria in shellfish harvesting waters has long been used as an indicator organism of less numerous and less easily detectable pathogenic organisms. Although fecal coliforms are found in the intestines of all warm-blooded animals, septic systems are often blamed as the source of the bacteria in surface waters. In the absence of direct surface breakthrough and runoff from failing septic systems, subsurface movement of coliforms through the soil absorption system and the groundwater is a suspected pathway for contamination.

Attenuation of bacteria and viruses by the soil adsorption system is through physical and biological means and is affected by soil properties, water table conditions, and even system design and maintenance. Simply stated, intestinal bacteria survive best under anaerobic conditions and rapidly die off under aerobic conditions. Bacteria can be short-circuited to the groundwater when the water table is in or near the drainfield trenches. Whereas the lateral movement of bacteria in groundwater can be highly variable, the presence of an adequate vadose (unsaturated) zone beneath the drainfield is important to reducing the threat of bacterial transport.

MATERIALS AND METHODS

Site Selection

Four residences in Charleston County were chosen for this study based on their proximity to surface water, the age of the onsite system, and on the homeowner's willingness to participate in the study. The sites are located on James Island (JI), Yonges Island (YI), Isle of Palms (IP), and Ravenel (RA). The locations of Charleston County and each site within the county are shown in Figures 1-5. Each site has an onsite system that was installed in accordance with the current onsite regulations (R. 61-56, effective 1986). Scaled site maps that show each system layout and system description are included with the data figures and discussion for each site. Copies of the onsite permits are included as Appendix A. Toward the end of the project, the homeowners completed a septic system performance survey regarding their experiences and/or problems with their onsite system.

Monitoring Well Installation

Each site had six shallow groundwater monitoring wells installed in November, 1995. A DHEC hydrogeologist who is a certified well driller assisted with well placement and installation. One upgradient, one in-field (i.e., between two trenches in the drainfield) and four downgradient wells were installed per site. The purpose of an upgradient well was to establish the background water quality conditions, i.e., outside of the influence of the drainfield. An in-field well was used to measure the quality of the groundwater as affected by effluent treated solely by the vadose zone (unsaturated zone) immediately beneath the drainfield. The purpose of the downgradient wells was to measure the movement of the septic tank effluent plume and the transformations of certain effluent constituents with distance from the drainfield. Wells 3, 4, and 5 at each site were located 10, 15, and 25 feet, respectively, downgradient from the edge of the drainfield. Distances from the onsite system to well 6 varied from site to site, with well 6 typically being the well closest to the surface water.

The wells were constructed of 2-inch, threaded, schedule 40 PVC pipe, 0.01-inch slotted PVC screen and PVC well points. The wells were installed using 3 1/4-inch hand soil augers. Since it is very difficult to auger much below the surface of the water table using hand soil augers, each well was installed only to the depth of the water table at time of installation. With a well point on the bottom of each well, a few additional inches were gained by pounding the well in further immediately after placing it in the ground. The wells were backfilled with filter-pack sand and bentonite pellets. Since the wells were of a temporary nature, no cement was used. The wells were terminated just below the ground surface and protected with turf-style valve boxes and locking caps (see Fig. 6 for a typical well construction diagram).

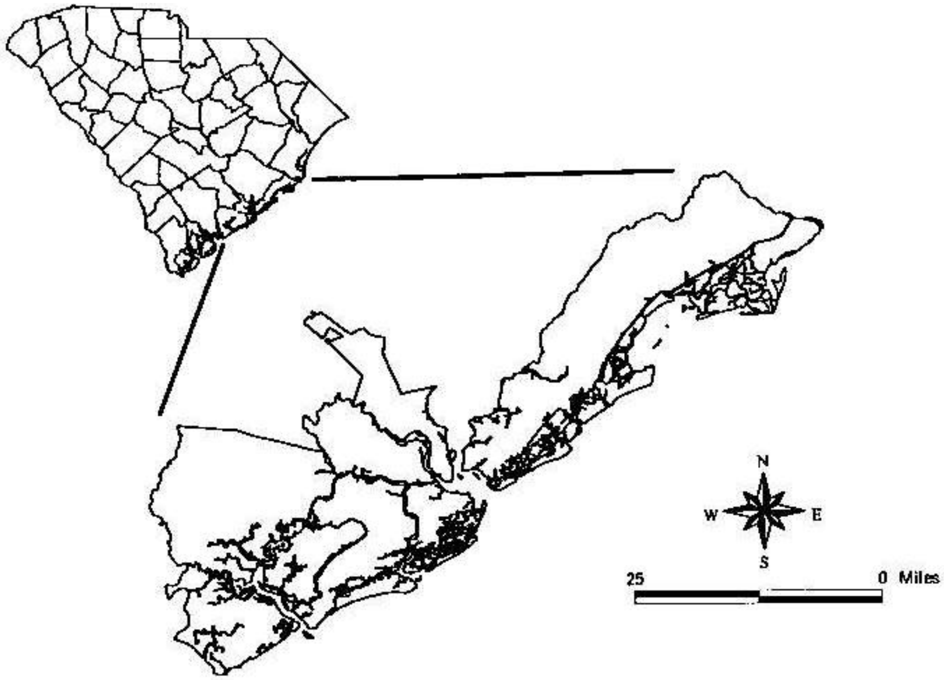

Figure 1 Map of Charleston County.

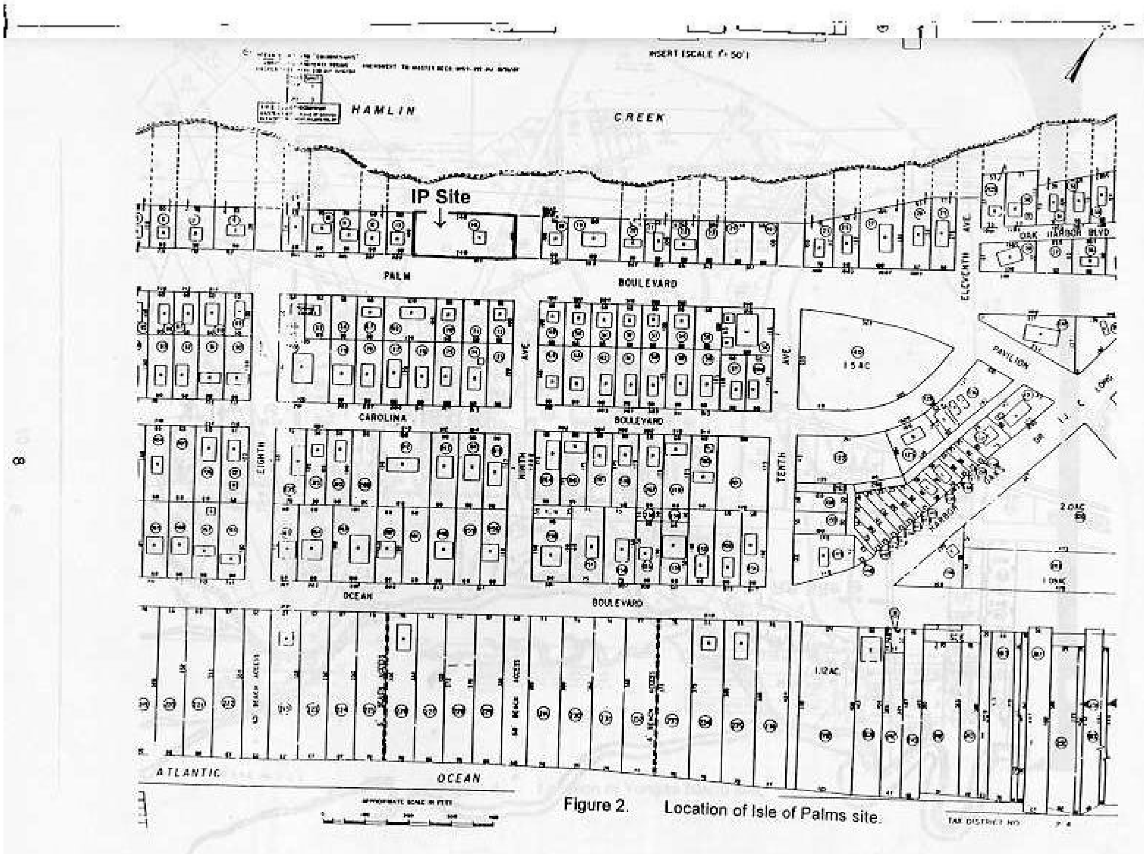

Figure 2. Location of Isle of Palms site.

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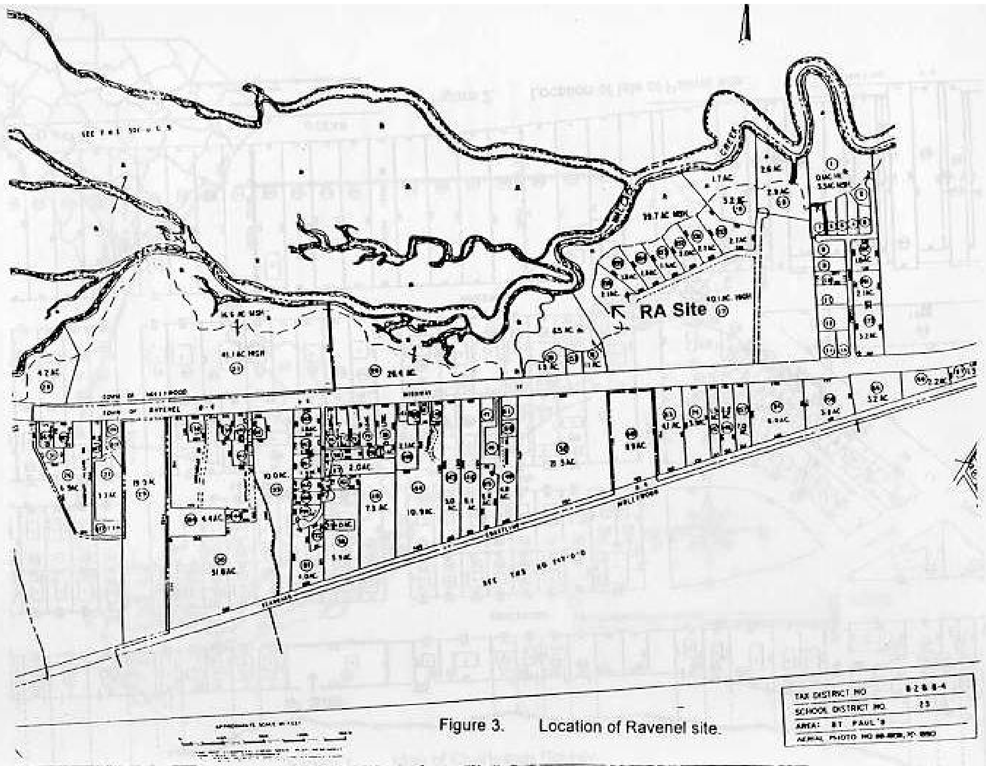

Figure 3. Location of Ravenel site.

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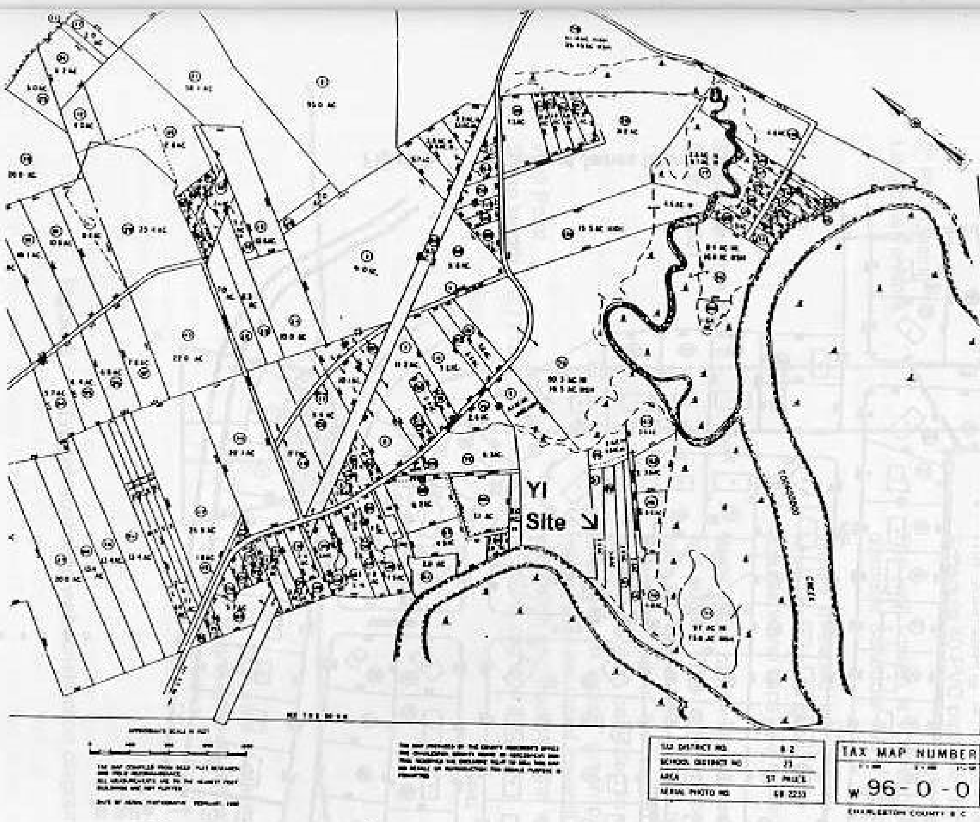


Figure 4. Location of Yonges Island site.

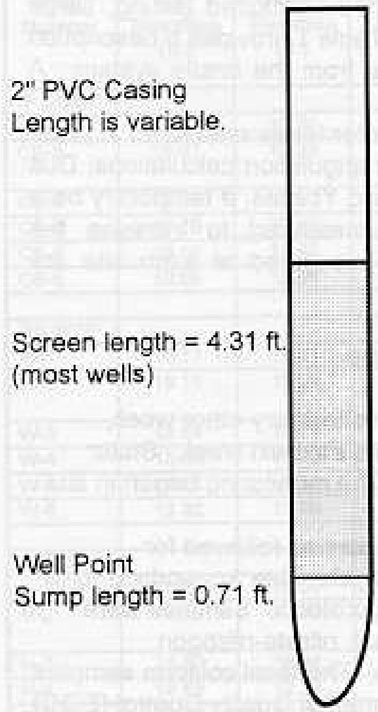
Figure 5. Location of James Island site.

This gave homeowners the ability to mow without interference. The wells were provided with locking caps and padlocks.

The wells were developed by several methods, included bailing, surge block and bilge pumping, and peristaltic pumping. Table 1 provides a description of each well, its gradient direction, and its distance from the onsite system. A negative distance is used for the upgradient wells.

Well elevations were surveyed and groundwater levels measured in order to determine direction of groundwater flow using triangulation calculations. Due to the fairly linear layout of the wells at the JI, IP, and YI sites, a temporary bore hole was augered, surveyed, and water level measured to increase the triangulation measurements. Flow directions as measured at each site are shown on the site maps.

TYPICAL MONITORING WELL CONSTRUCTION DIAGRAM



- The well casing is constructed of 2" diameter Schedule 40 PVC pipe with threaded joints.
- The well screen is constructed of 0.01" slot, 2" diameter Schedule 40 PVC pipe.
- Where threaded joints were not possible (i.e., when screen lengths were cut), glued joints (couplers and caps) were used.
- Wells were hand-installed using a 3" diameter soil auger. The annular space was backfilled with #1 filter sand (20/40 mesh) to 1-2 feet above the top of the screen. Bentonite chips (3/8") were then backfilled to within 6" of the top of casing. A 9x8x6" green plastic turf box was placed over the top of the well at ground level for protection and access. The well is secured with a locking cap and padlock.

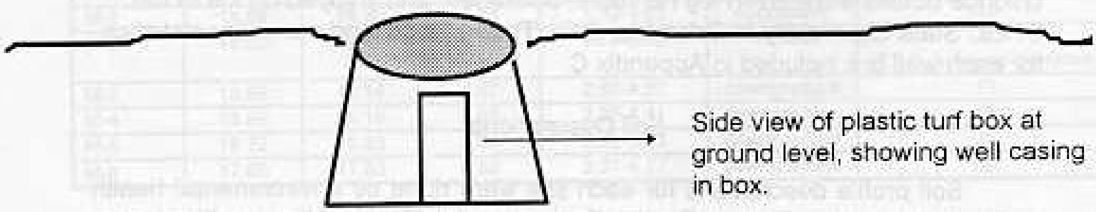


Figure 6. Typical monitoring well construction diagram.

Groundwater Monitoring

Groundwater samples were collected at each site every other week, alternating two sites one week and the other two sites the next week. Static water levels were taken once a week at each site. The monitoring began in late November 1995, and ended in late June, 1996.

Standard DHEC groundwater sampling protocol was followed for collecting, preserving, and shipping samples for analysis. See Appendix B for a more thorough description of this project's sampling protocol. Samples were collected for fecal coliform (MPN/100 ml; A-1 method), nitrate-nitrogen, ammonium-nitrogen, total phosphorus, and chloride. The fecal coliform samples were analyzed at the DHEC Trident District Environmental Quality Control (EQC) Office laboratory. The nutrient sample bottles (for nitrogen and phosphorus) were acidified at the EQC lab with 2 ml of 1:1 sulfuric acid. The nutrient and chloride bottles were given log numbers, packaged, and shipped on ice to the DHEC State Laboratory in Columbia, S.C. The raw data and summary statistics for each well are included in Appendix C.

Soil Descriptions

Soil profile descriptions for each site were done by environmental health professionals at the Trident District Environmental Health Office in Charleston County. Among other duties, this office administers the DHEC septic tank program for Charleston, Dorchester, and Berkeley counties. Since one of the main objectives of this study was to determine the effectiveness of the six-inch separation distance between the seasonal high water table (SHWT) and the trench bottom, we felt it was important to have the SHWT determined by those who run the septic tank program. This could also allow for a comparison of the estimated SHWT using soil color (as done by the health departments) and the SHWT as measured in the wells during this study.

The soil boring logs are included in Appendix D. Soil boring logs were not done on each well during installation because several wells were installed simultaneously and the personnel were not available to describe each bore hole. At the IP site the auger used by the health department staff only went to 48 inches deep, therefore the descriptions are only for the top four feet. At the JI site, the soil profile descriptions are from 1986, when the health department conducted a re-evaluation of the site. We chose not to do additional soil borings because we did not want to disturb the extensive landscaping of this home any more than had already been done by well installation. The borings done at the YI and RA sites extended to the water table, essentially the length of the wells.

Rainfall

Rainfall data was gathered from the S.C. State Climatology Office for the four monitoring stations that were closest to the study sites. The rainfall data is included with the data figures and discussion for each site.

Table 1. Monitoring well descriptions.

Well Number	TOC* Elevation (ft.)	Ground Elevation (ft.)	Total Well Depth** (ft.)	Screened Interval Depth from TOC (ft.)	Gradient Direction	Distance from Septic System (ft.)
IP SITE						
CB-1	19.06	19.26	9.13	4.20-8.51	upgradient	-22
CB-2	19.07	19.38	9.27	4.34-8.65	in-field	0 (5 ft. between trenches)
CB-3	19.37	19.50	9.23	4.30-8.61	downgradient	10
CB-4	19.10	19.38	9.29	4.36-8.67	downgradient	15
CB-5	19.59	19.90	9.18	4.25-8.56	downgradient	25
CB-6	19.66	19.95	9.61	4.68-8.99	side-gradient?	105
RA SITE						
W-1	19.17	19.31	8.60	3.67-7.98	upgradient	-40
W-2	19.11	19.26	7.28	2.35-6.66	in-field	0 (4.3 ft. between trenches)
W-3	18.64	18.73	9.22	4.29-8.60	downgradient	10
W-4	18.59	18.72	9.48	4.55-8.86	downgradient	15
W-5	18.25	18.34	8.87	3.94-8.25	downgradient	25
W-6	13.92	13.99	5.60	2.64-4.98	side-gradient	185 (approx.)
YI SITE						
N-1	18.26	18.56	8.25	3.32-7.63	upgradient	-37
N-2	19.50	19.67	9.81	4.88-9.19	in-field	0 (3.9 ft. between trenches)
N-3	19.80	19.94	9.85	4.92-9.23	downgradient	10
N-4	19.69	19.72	9.85	4.92-9.23	downgradient	15
N-5	19.55	20.06	10.22	5.29-9.60	downgradient	25
N-6	19.68	19.89	8.87	3.94-8.25	side-gradient	26
JI SITE						
M-1	18.69	18.90	3.78	1.30-3.63	upgradient	-20
M-2	19.23	19.40	4.34	1.78-3.72	in-field	0 (3.5 ft. between trenches)
M-3	18.88	19.14	4.67	2.66-4.52	downgradient	10
M-4	18.99	19.15	5.03	2.06-4.41	downgradient	15
M-5	18.72	18.83	5.65	2.82-5.03	downgradient	25
M-6	17.68	17.83	4.89	2.37-4.27	downgradient	107

*TOC = top of well casing
Elevations are relative to a temporary benchmark established at 20 feet above sea level.
**The total well depth is measured from the inside of the well point or cap where the light buzzer touches to the TOC.

RESULTS AND DISCUSSION

Rainfall

According to the Charleston County Soil Survey, the average annual precipitation is 49.1 inches. This is almost totally in the form of rain. For the months of December through June, the average precipitation totals 24.1 inches. Also for those months, one year in ten will have less than 7.4 inches and one year in ten will have more than 39.8 inches of precipitation.

The rainfall recorded at the stations closest to each site for the sampling period of late November to mid June is as follows:

IP site ------	12.53 inches
RA site -----	13.19 inches
YI site ------	16.54 inches
JI site -------	11.16 inches

Isle Of Palms Site

Location

This site is located on Hamlin Creek which feeds into the Atlantic Intracoastal Waterway (ICWW, watershed 03050202-060). The ICWW is a Class SB water. Class SB is defined as tidal saltwaters suitable for primary and secondary contact recreation, crabbing, and fishing, except harvesting of clams, mussels, or oysters for market purposes or human consumption; also suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora.

Hamlin Creek is a diurnal waterbody with a mean tide range of 5.09 feet, a spring tide of 5.90 feet, and a mean tide level of 2.75 feet. Shellfish harvesting in Hamlin Creek is restricted from its confluence with Swinton Creek to the ICWW, which includes this site location.

Water quality data from the shellfish water quality sampling station closest to this site show that 23% of the samples exceeded an MPN of 43/100 ml over 30 sampling events which occurred from February 1994 to April 1996. A surface water sample collected off the dock at this site on July 9, 1996, was found to have a fecal coliform level of 46 MPN/100 ml and a salinity of 34%. The most likely source may be the treated wastewater discharged from a yacht which is moored at this dock.

The location of the onsite system, the monitoring wells, the groundwater flow direction, and a description of the system can be seen in Figure 7.

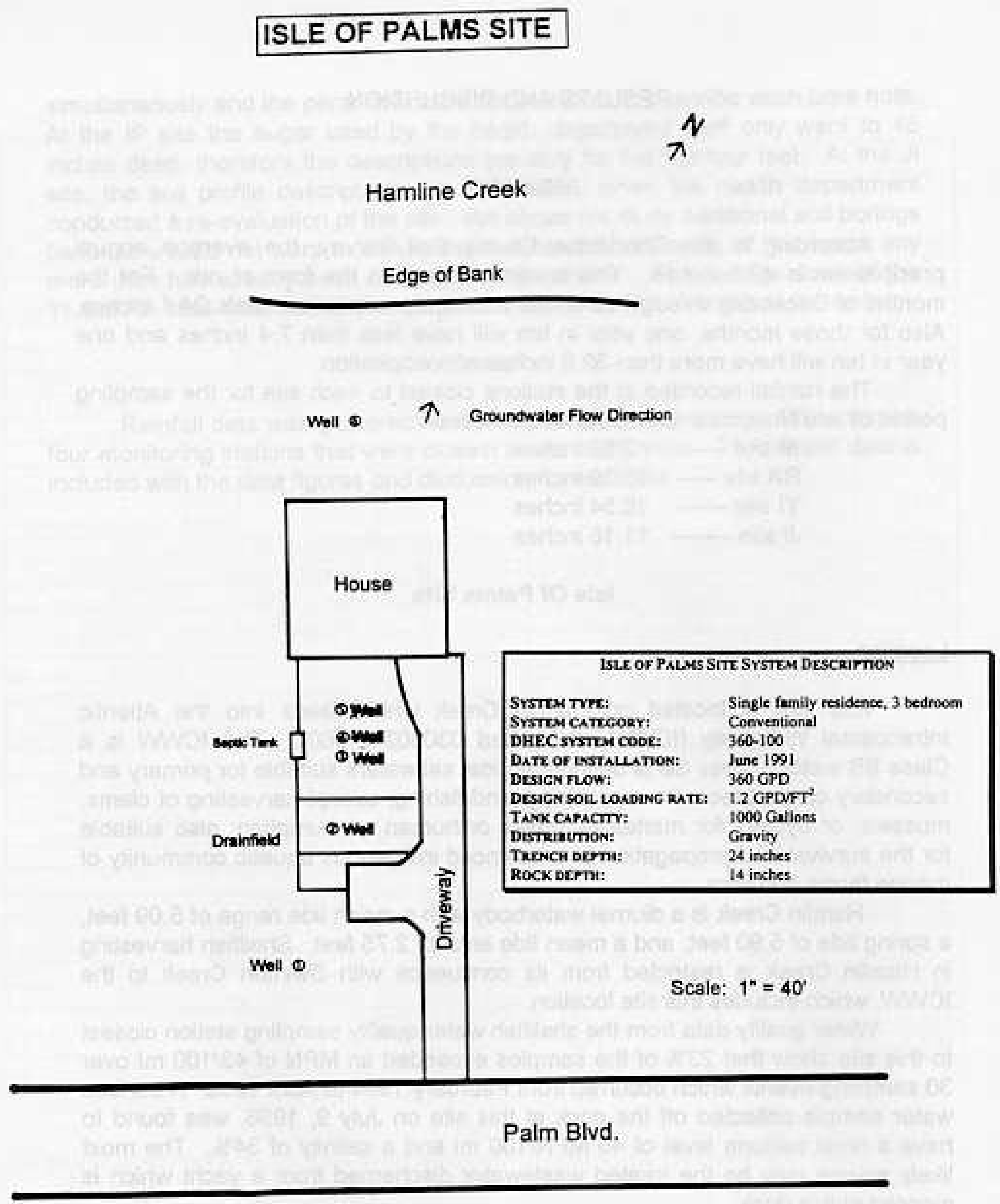


Figure 7. Isle of Palms site map.

Septic System Performance Survey

The performance survey as completed by the residents indicates that no problems have been experienced with this five year old system. With only two adults residing in this home and no garbage disposal, we assume that the loading to this system is well below its design capacity. A discrepancy between the permit and the survey was noted, however. The permit was for a three bedroom home, and the survey response indicated that it is a four bedroom home.

Groundwater Levels

As stated previously, the six groundwater monitoring wells were installed in November, 1995. In most years, the water table would rise throughout the winter to its 'seasonal high' until evapotranspiration by plants in the spring and summer would again draw it back down. We fully anticipated the water table to rise above the level at which the wells were installed. However, rainfall levels for the 1995-96 winter season were about 10-12 inches below normal (Fig. 8 and Table 2).

Figure 9 illustrates the relatively steady decline in water table levels throughout the monitoring period with occasional rises following rain events. Well CB-5 in particular never yielded enough water to collect samples. This may have been due, in part, to the well's close proximity to several large live oak trees. Well CB-6 yielded only one sample. Water levels were taken on a weekly basis and water samples were taken every other week. Therefore, a temporary rise in water levels did not always coincide with a sampling event. Wells CB-5 and CB-6 were the two farthest wells downgradient from the septic system. As a consequence, the extent of the septic tank effluent plume could not be adequately characterized.

With regard to separation distance between the trench bottom and the seasonal high water table, the minimum 6-inch separation required by R.61-56 was never approached. The trench depth at the IP site was the conventional 24-inch depth. Throughout the study period, the water table below the drainfield was never higher than 8.27 feet below the ground surface. Therefore, the minimum separation distance between the trench bottom and the seasonal high water table (as measured by well CB-2) during the study was 6.27 feet. The maximum separation distance was 7.1 feet and the average separation distance was 6.71 feet.

Water Quality

The in-field well (CB-2) and downgradient wells (CB-3, CB-4) had persistently and substantially higher chloride levels than the upgradient well (CB-1), as illustrated in Figure 10. This indicates that the wells were located within the septic tank effluent plume. It may be reasonable to assume that CB-6 was

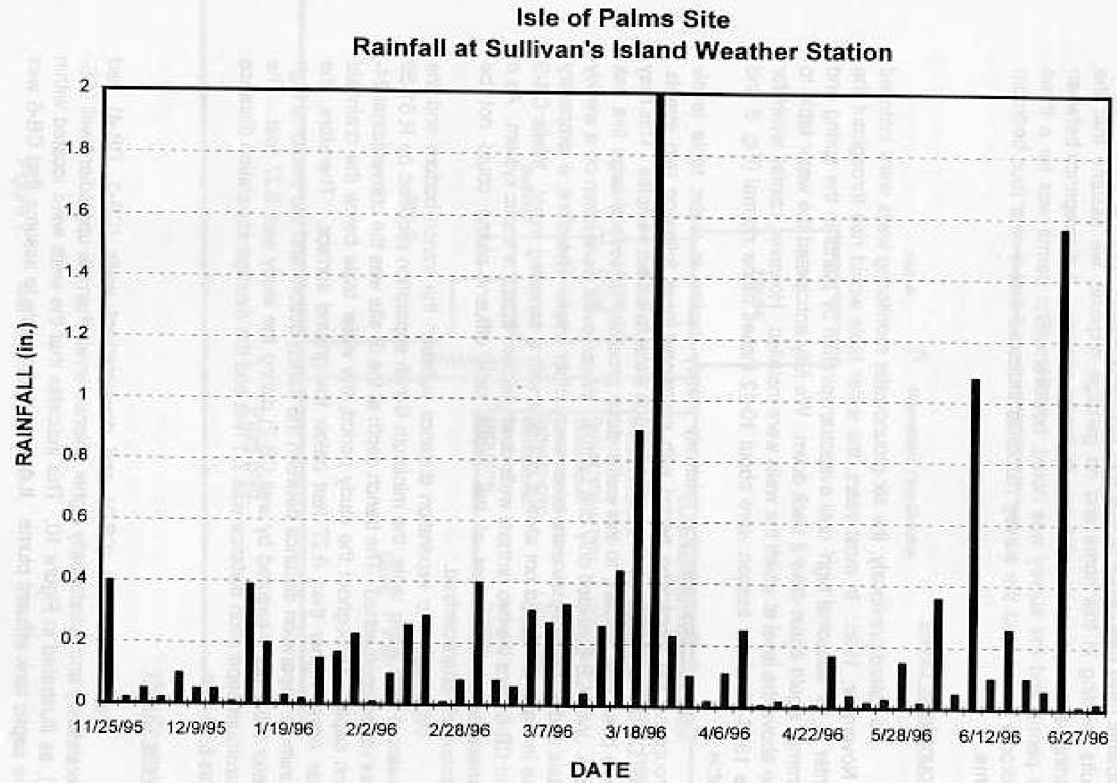


Figure 8. Rainfall at station closest to IP site.

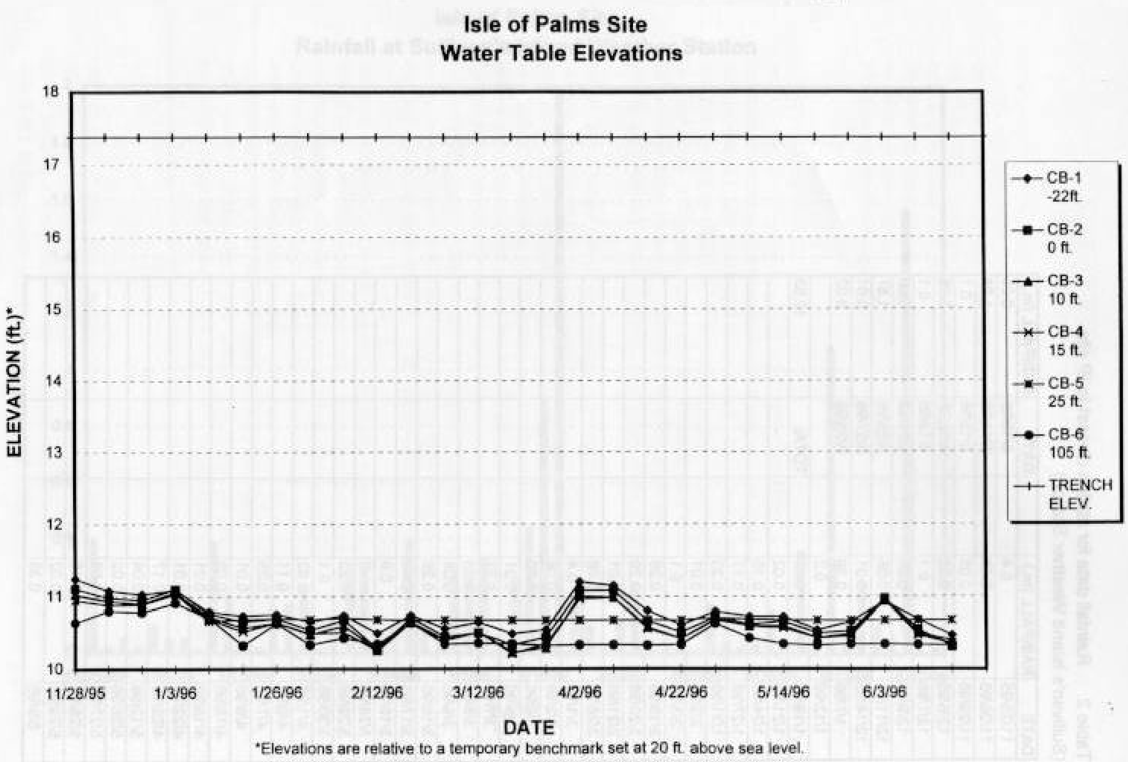


Figure 9. Water table elevations at IP site.

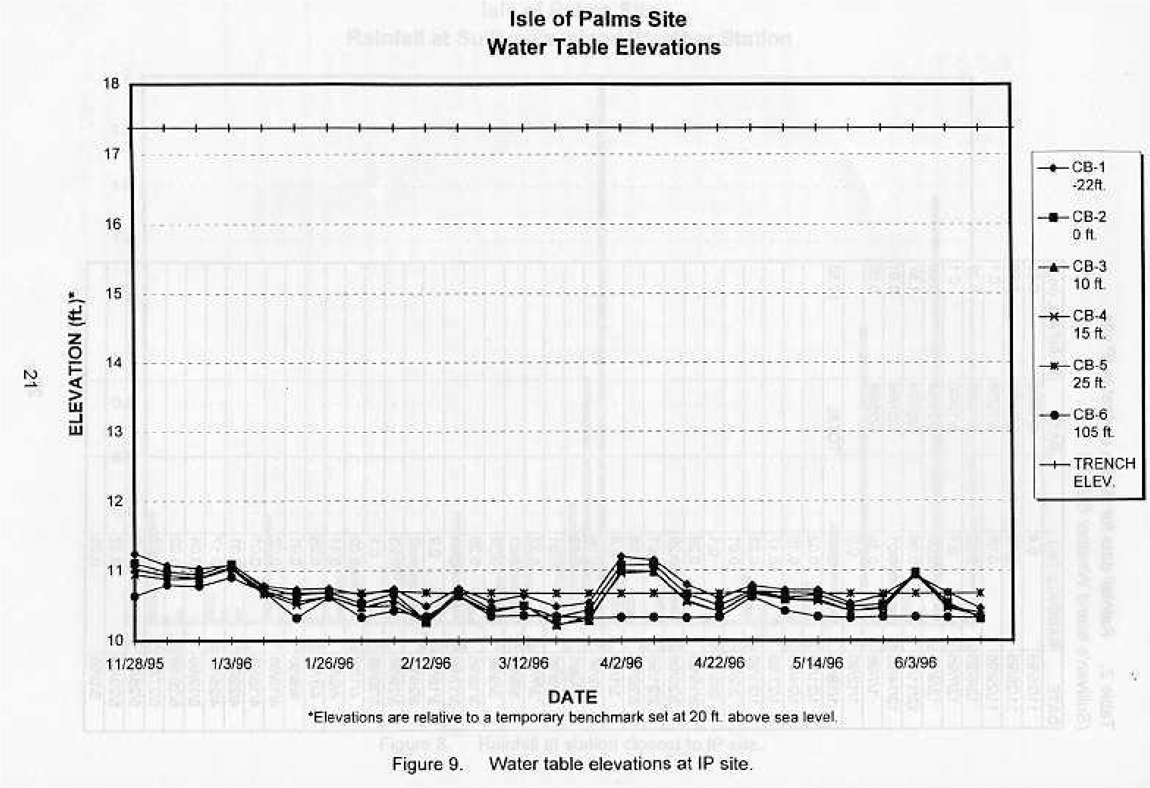


Figure 9. Water table elevations at IP site.

more side-gradient than downgradient. This assumption is based on its location in relation to the groundwater flow direction (see Fig. 7) and its one-time chloride measurement that was below background levels (Fig. 10).

Nitrate was the predominant form of nitrogen found at this site. This is not surprising given the overall aerobic nature of this site with its sandy soils and large vadose zone. Although nitrate levels were quite variable over time they were greatly and consistently above background levels (Fig. 11). This also supports the assertion that wells CB-2, CB-3, and CB-4 were within the effluent plume. These in-field and downgradient wells often exceeded nitrate drinking water standards (10.0 mg/l) reaching as high as 26.0 mg/l at 15 feet from the edge of the drainfield (well CB-4).

Background ammonium levels were below the detection limit except for a few transitory events (Fig. 12). Ammonium levels in the in-field and downgradient wells ranged from <0.05 to 0.14 mg/l, indicating a high degree of nitrification occurring under the drainfield. Figure 13 shows that mean ammonium levels were generally at or below background levels.

Total phosphorus (P) also was found to be consistently and substantially higher in the in-field and downgradient wells than the upgradient well, although a geographic trend downgradient could not be discerned (Fig. 14). In other words, there is no real tangible explanation for why wells CB-3 and CB-4 had higher P levels than well CB-2 (2.45 and 2.49 mg/l versus 1.68 mg/l, respectively).

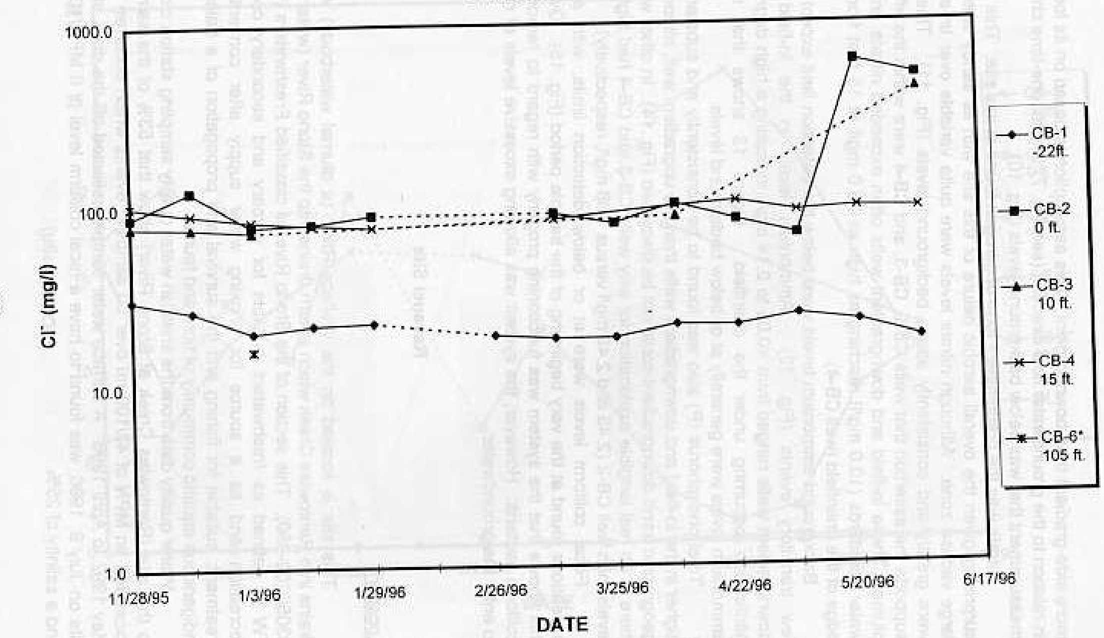
Fecal coliform levels were at or below detection limits, with a few exceptions found at the very beginning of the sample period (Fig. 15). Overall, this shows that the system was functioning properly with regard to removal of coliform bacteria. However, the system was allowing excessive levels of nitrate to enter the groundwater.

Ravenel Site

Location

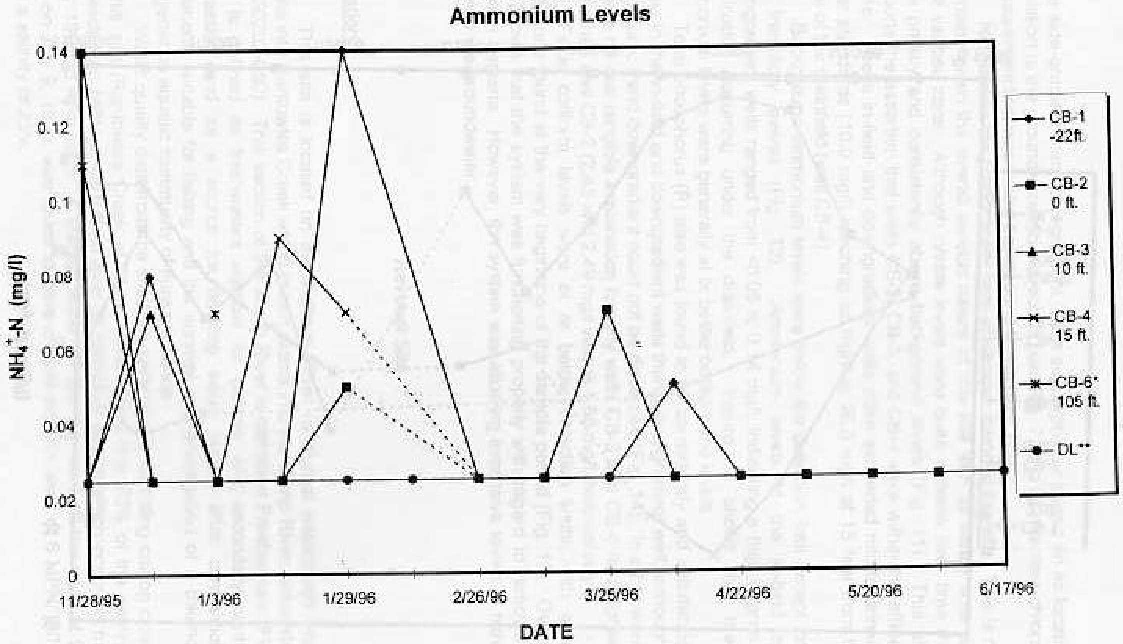
This site is located on the Wallace River (a diurnal waterbody) which drains into Rantowles Creek which in turn drains into the Stono River (watershed 03050202-050). This section of the Stono River is classified Freshwaters (FW). FW is defined as freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment; suitable for fishing and the survival and propagation of a balanced indigeneous aquatic community of flora and fauna.

Water quality data from the shellfish water quality sampling station closest to this site (Rantowles Creek at Stono River) show that 53% of the samples exceeded an MPN of 43/100 ml over 30 sampling events which occurred from May 1992 to April 1996. A surface water sample collected off the dock at this site on July 9, 1996, was found to have a fecal coliform level of 6 MPN/100 ml and a salinity of 25%.



*CB-6 produced only one sampling event; CB-5 had none

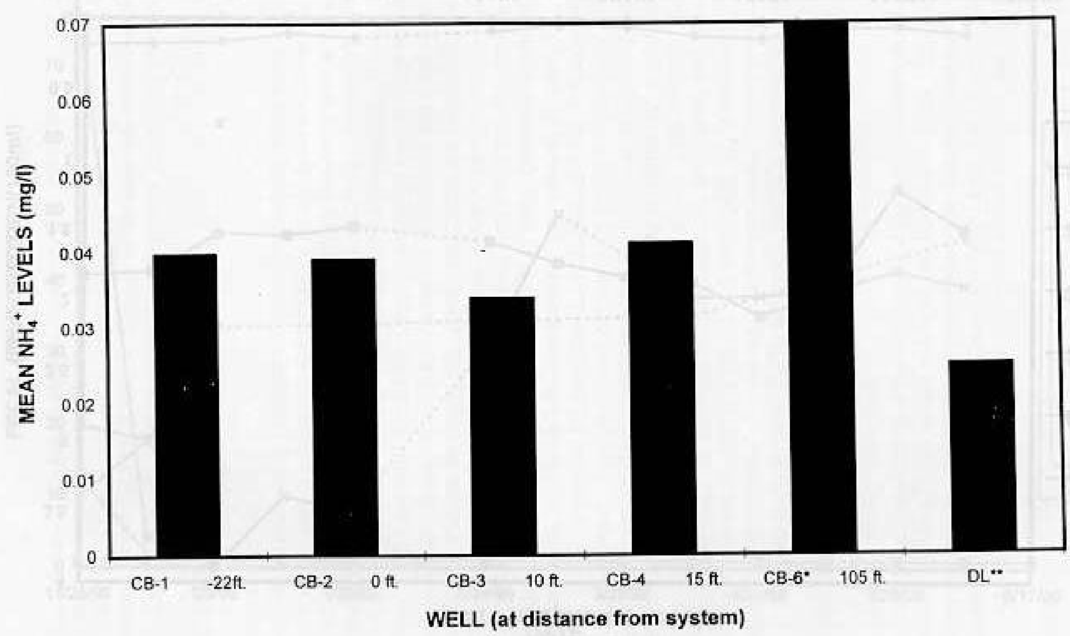
Figure 10. Chloride levels at IP site.



*CB-6 produced only one sampling event; CB-5 had none

**DL = detection limit of 0.025 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.05 mg/l

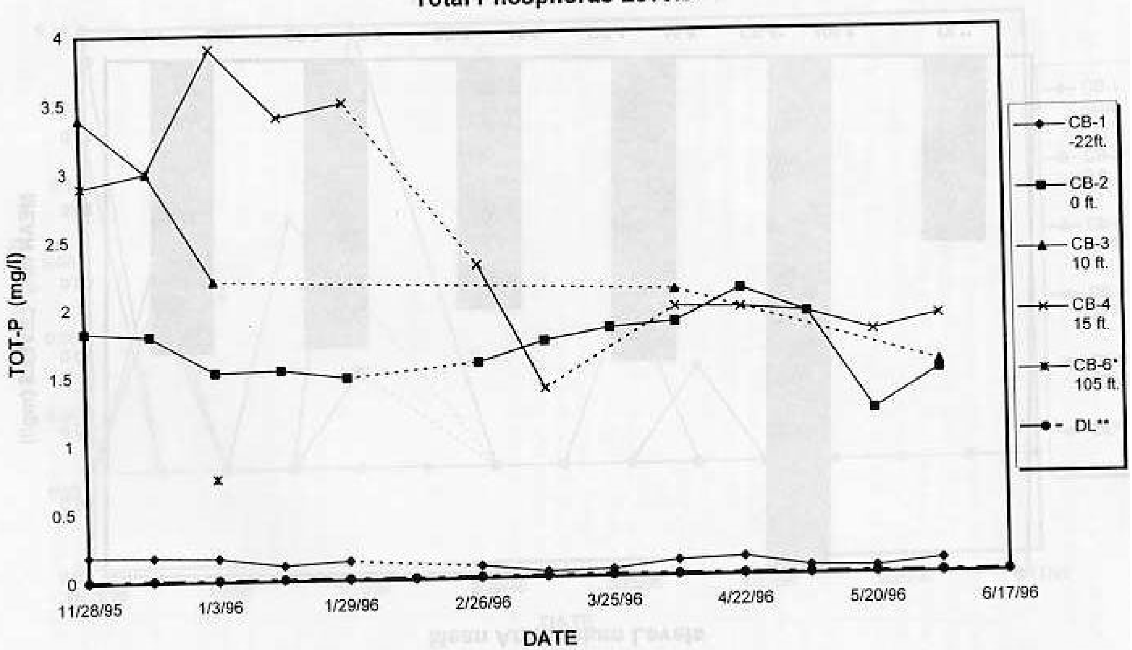
Figure 12. Ammonium levels at IP site.



*CB-6 data is from 1 observation

**DL = detection limit of 0.025 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.05 mg/l

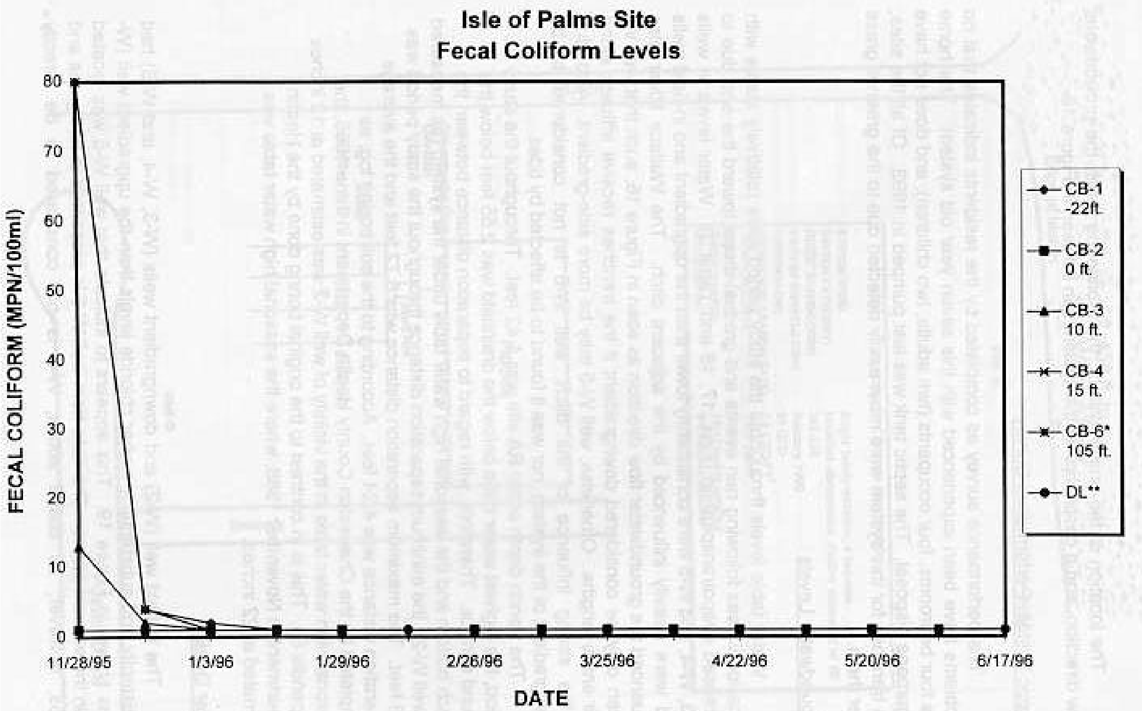
Figure 13. Mean ammonium levels at IP site.



*CB-6 produced only one sampling event; CB-5 had none

**DL = detection limit of 0.01 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.02 mg/l

Figure 14. Total phosphorus levels at IP site.



*CB-6 produced only one sampling event; CB-5 had none

**DL = detection limit of 1 MPN/100 ml used for data interpretation, which is one-half the laboratory detection limit of <2 MPN/100 ml

Figure 15. Fecal coliform levels at IP site.

The location of the onsite system, the monitoring wells, the groundwater flow direction, and a description of the system can be seen in Figure 16.

Septic System Performance Survey

The performance survey as completed by the residents indicates that no problems have been experienced with this seven year old system. The home has four bedrooms, four occupants (two adults, two children), and does not have a garbage disposal. The septic tank was last pumped in 1993. Of all the sites, the trenches for this system were most easily detected due to the greener grass over them.

Groundwater Levels

Water table levels throughout the study period were relatively stable with occasional rises following rain events and gradual drops toward the end due to increased evapotranspiration (Figs. 17, 18 and Table 3). Water levels in wells W-3, W-4, and W-5 were consistently lower than the upgradient and in-field wells and were heavily influenced by the adjacent ditch. The Wallace River also influenced the groundwater flow direction as seen in Figure 16, such that well W-5 can only be considered downgradient if the trenches receive effluent along their entire lengths. Otherwise, well W-5 may be more side-gradient. Also, due to the strong influence of

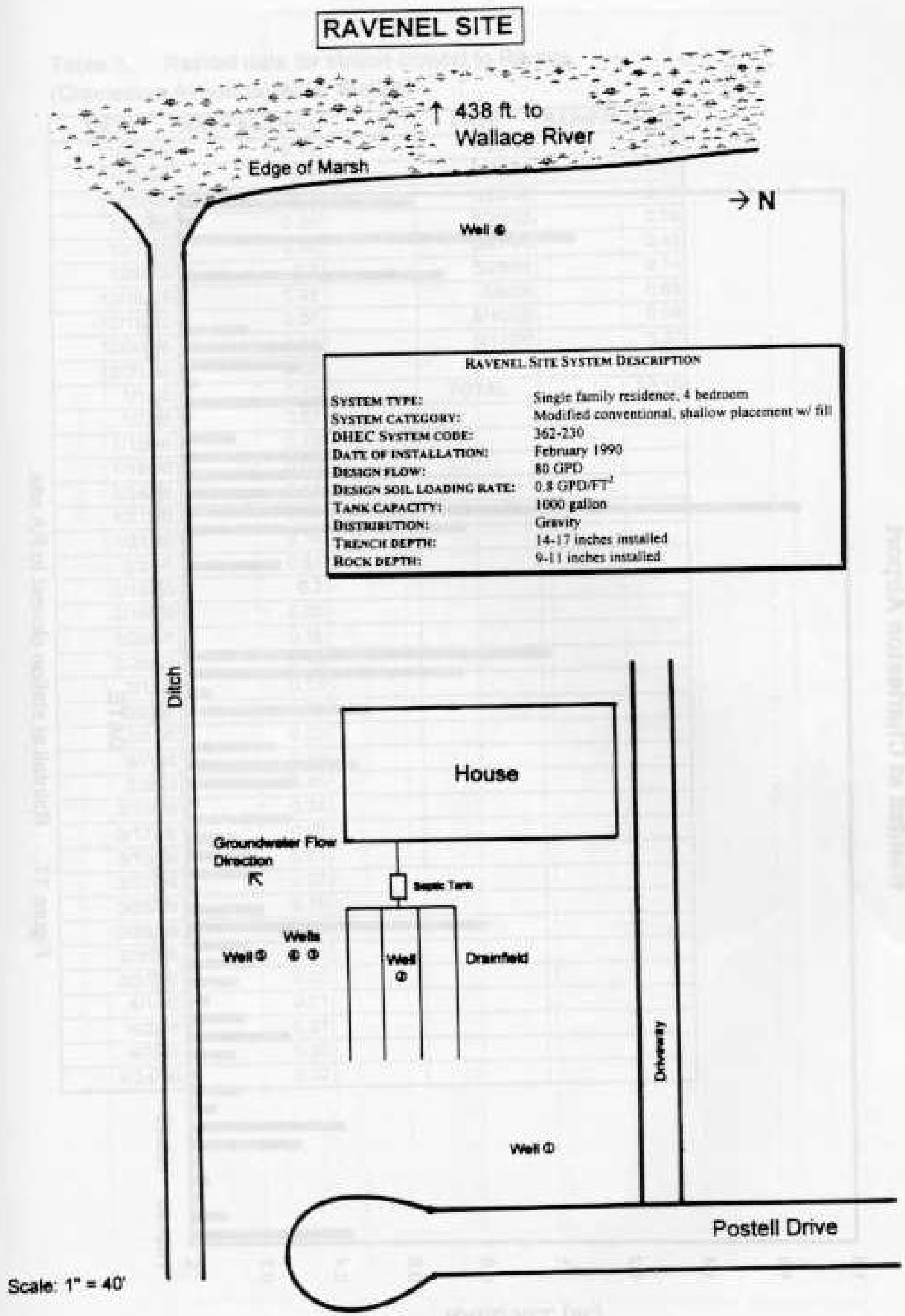


Figure 16. Ravenel site map.

Table 3. Rainfall data for station closest to RA site.
(Charleston Airport Weather Station)

DATE	RAINFALL (in.)	DATE	RAINFALL (in.)
11/24/95	0.44	4/26/96	0.76
11/25/95	0.1	4/30/96	1.67
11/29/95	0.02	5/22/96	0.46
12/6/95	0.05	5/26/96	0.58
12/7/95	0.02	5/27/96	0.43
12/9/95	0.3	5/28/96	0.14
12/18/95	0.42	6/9/96	0.65
12/19/95	0.07	6/10/96	0.04
12/30/95	0.14	6/11/96	0.37
12/31/95	0.02		
1/1/96	0.12	**TOTAL**	13.19
1/7/96	0.27		
1/12/96	0.15		
1/19/96	0.05		
1/24/96	0.13		
1/27/96	0.17		
1/31/96	0.16		
2/2/96	0.81		
2/15/96	0.2		
2/16/96	0.02		
2/20/96	0.16		
2/28/96	0.17		
3/1/96	0.13		
3/2/96	0.28		
3/6/96	0.03		
3/7/96	0.29		
3/8/96	0.46		
3/16/96	0.24		
3/17/96	0.02		
3/18/96	0.51		
3/27/96	0.07		
3/28/96	0.75		
3/29/96	0.99		
3/30/96	0.01		
3/31/96	0.02		
4/1/96	0.01		
4/2/96	0.01		
4/7/96	0.26		
4/24/96	0.02		

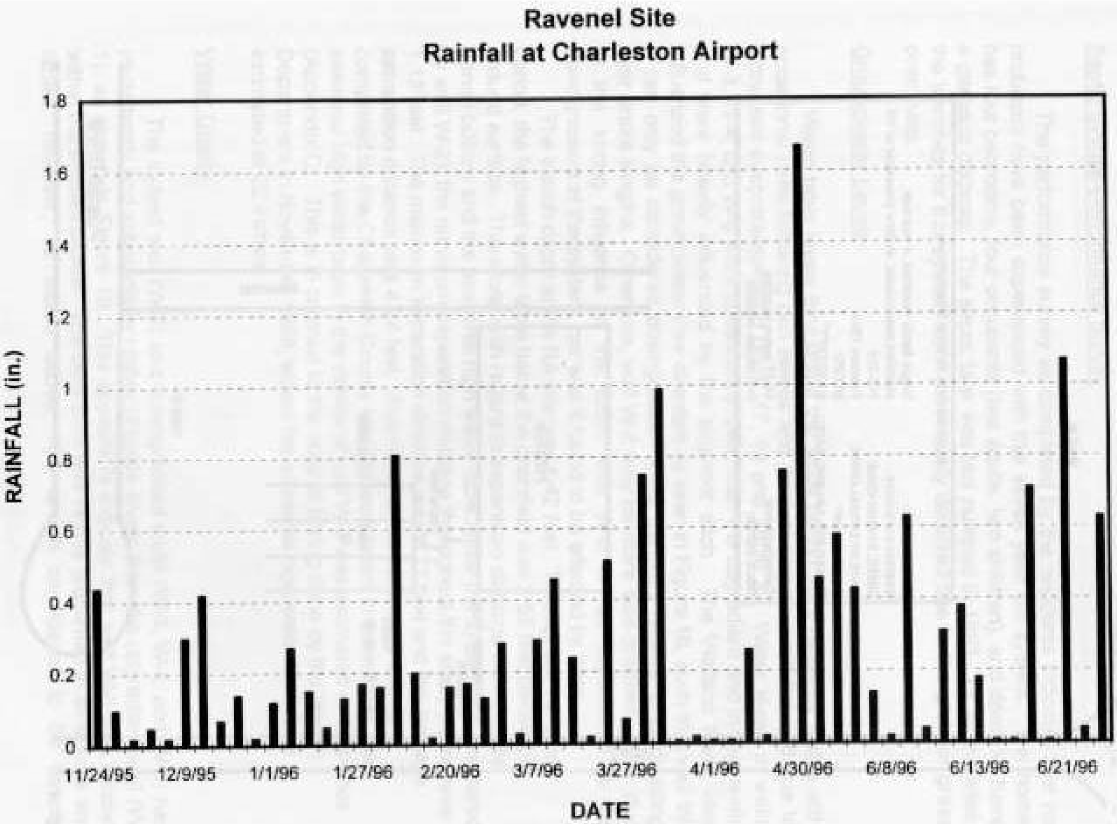


Figure 17. Rainfall at station closest to RA site.

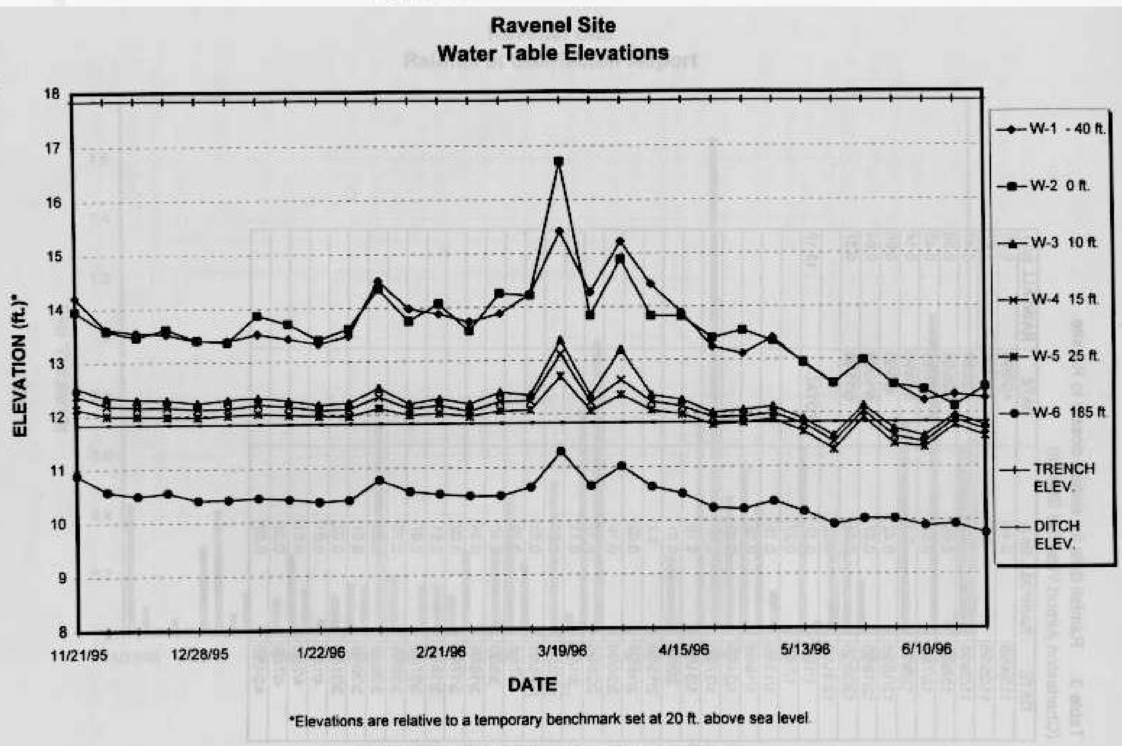


Figure 18. Water table elevations at RA site.

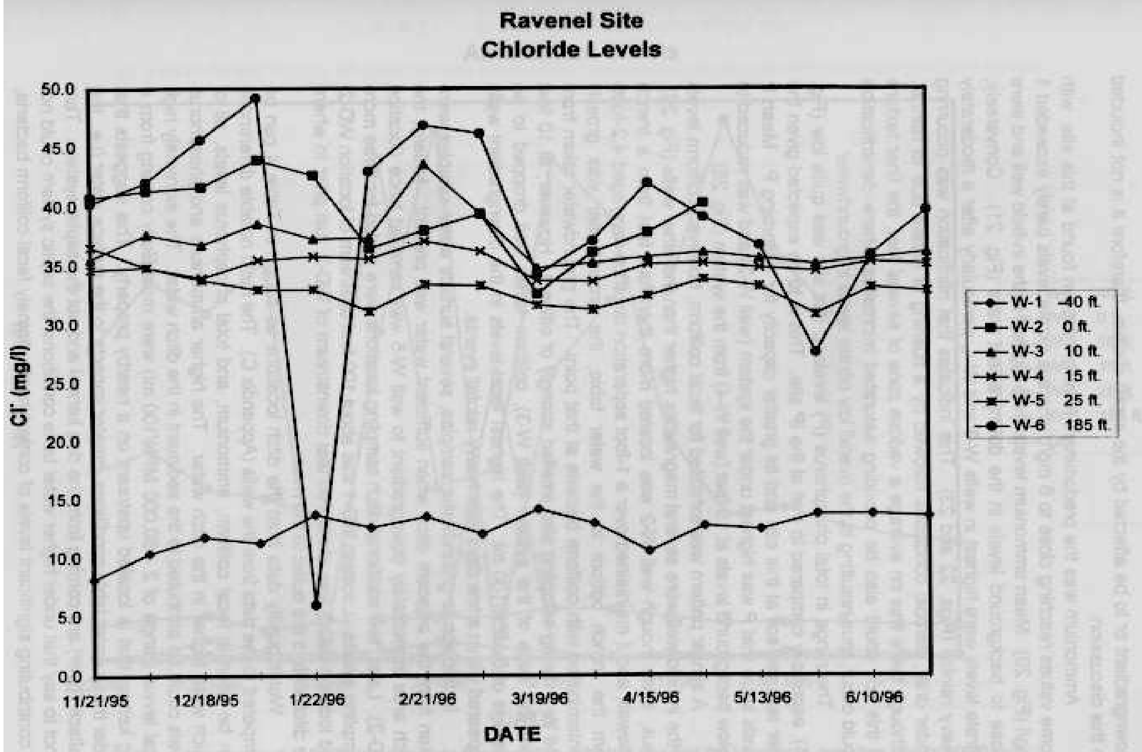
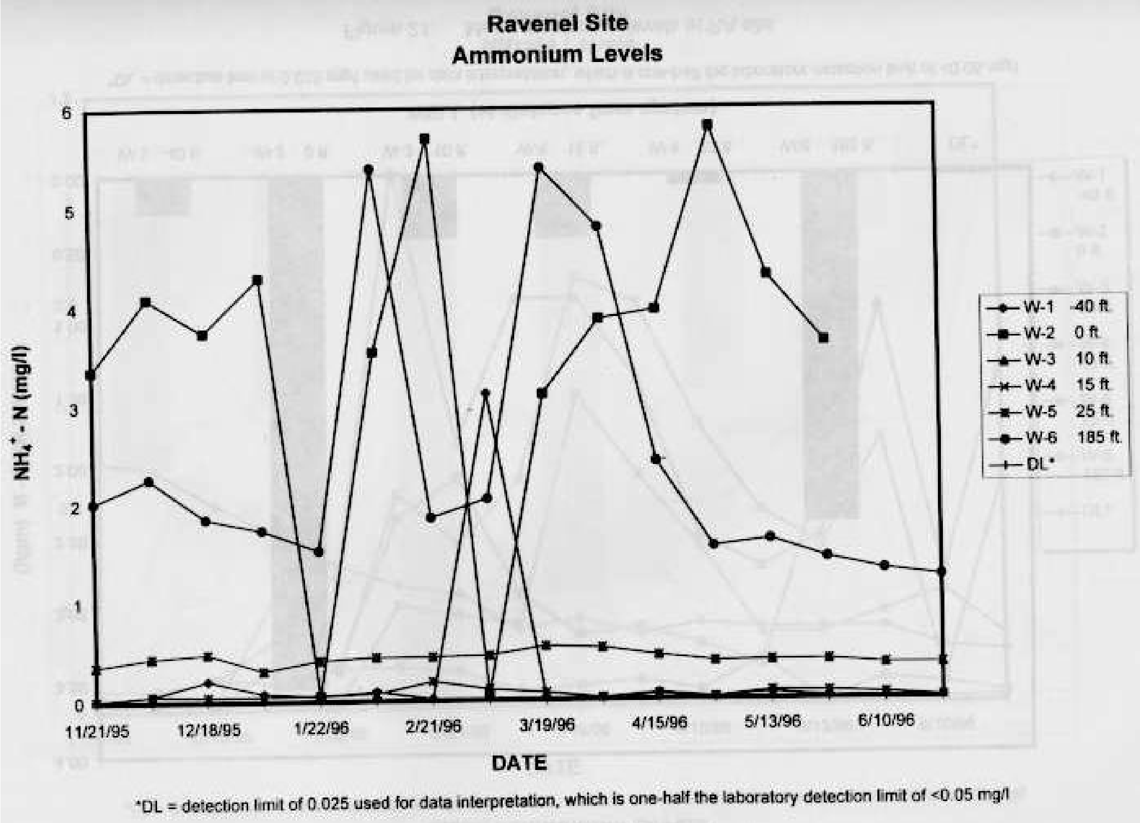


Figure 19. Chloride levels at RA site.



*DL = detection limit of 0.025 used for data interpretation, which is one-half the laboratory detection limit of <0.05 mg/l

Figure 20. Ammonium levels at RA site.

the ditch, well W-6 is not considered to be downgradient of the system, nor was it found to be affected by tides.

The trench depth at the RA site was 1.42 feet. Throughout the study period, the highest water table below the drainfield was 2.55 feet below the ground surface. Therefore, with regard to separation distance between the trench bottom and the seasonal high water table under the system (as measured by well W-2), the minimum separation distance throughout the study period was 1.13 feet. The maximum separation distance was 5.72 feet and the average separation distance was 4.24 feet. According to the soil boring log, as completed by the Charleston County Health Department in June 1996, the seasonal high water table in the vicinity of well W-2 was estimated at 12 inches (Appendix D). This is in contrast to the original boring done by the Health Department in November 1988, where the seasonal high water table was estimated at 22 inches.

Water Quality

The in-field well (W-2) and downgradient wells (W-3, W-4, and W-5) had persistently and substantially higher chloride levels than the upgradient well (W-1), as shown in Figure 19. This appears to indicate that well W-5 was located within the effluent plume. The data from well W-6 is presented in all figures and tables, however, as stated above, W-6 is not considered to be directly downgradient or to be affected by the septic system, therefore it is not included in this discussion.

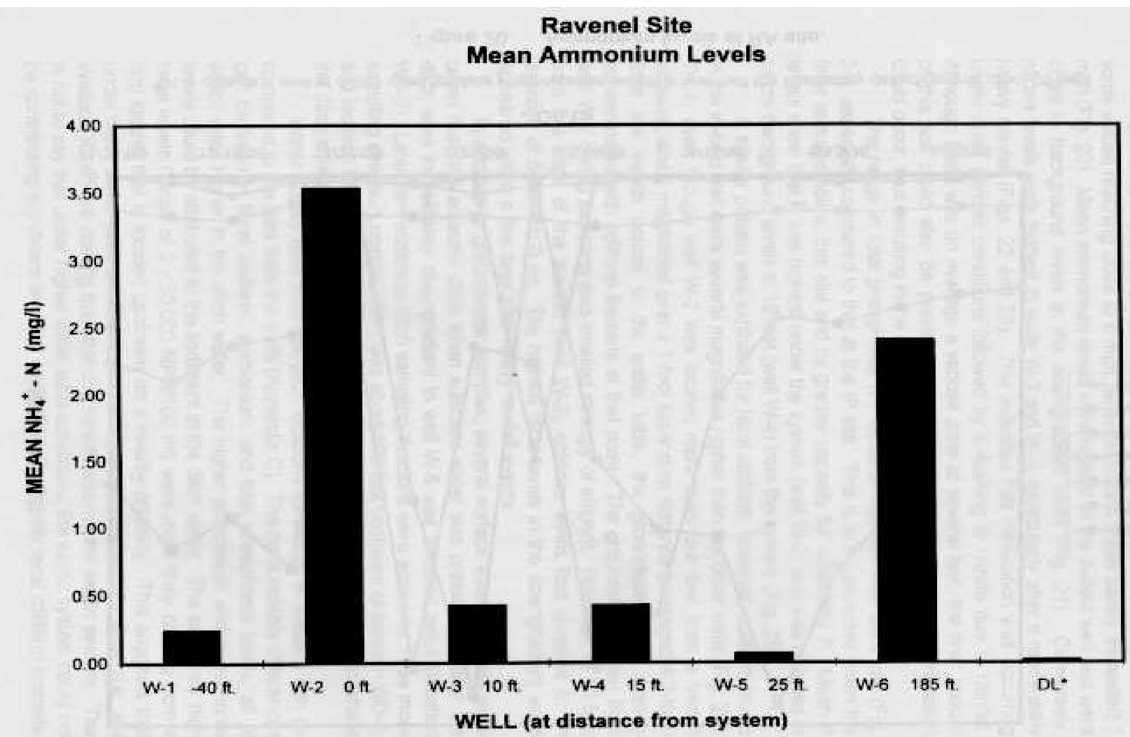
Ammonium was the predominant form of nitrogen found at this site, with some values reaching close to 6 mg/l, whereas nitrate levels barely exceeded 1 mg/l (Fig. 20). Mean ammonium levels were highest in the in-field well and were close to background levels in the downgradient wells (Fig. 21). Conversely, nitrate levels were highest in wells W-3 and W-4, particularly after a moderately heavy rainfall (Figs. 22 and 23). This indicates that nitrification was occurring under drier, aerobic conditions followed by a flushing of nitrate due to rainfall. Although there was on average a vadose zone of several feet, the finer texture of this soil could also be providing saturated microsites where denitrification could occur, thus resulting in the overall low nitrate levels in groundwater.

The range in total phosphorus (P) levels at this site was quite low (Fig. 24), especially compared to that at the IP site. This is to be expected given the finer textured soil at this site and its greater capacity for adsorbing P. Mean P levels show that P was highest under the system (well W-2) and was reduced to below background levels at 15 feet (well W-4) from the system (Fig. 25).

A similar pattern was exhibited for fecal coliform, however, coliform levels in the in-field well were several magnitudes higher than the other wells (Fig. 26). Thus, even though well W-2 was located more than four feet from a trench sidewall, and it maintained over a 1-foot separation distance (averaged 4.2-foot) from the trench bottom to the water table, the groundwater was grossly contaminated with coliform bacteria at that point. The groundwater taken from well W-2 during sampling also smelled strongly of effluent. However, at 10 feet from the edge of the system (well W-3), coliform levels had dropped to an average of 5 MPN/100 ml. The highest fecal levels in the downgradient wells appeared within a few days after heavy rainfall events.

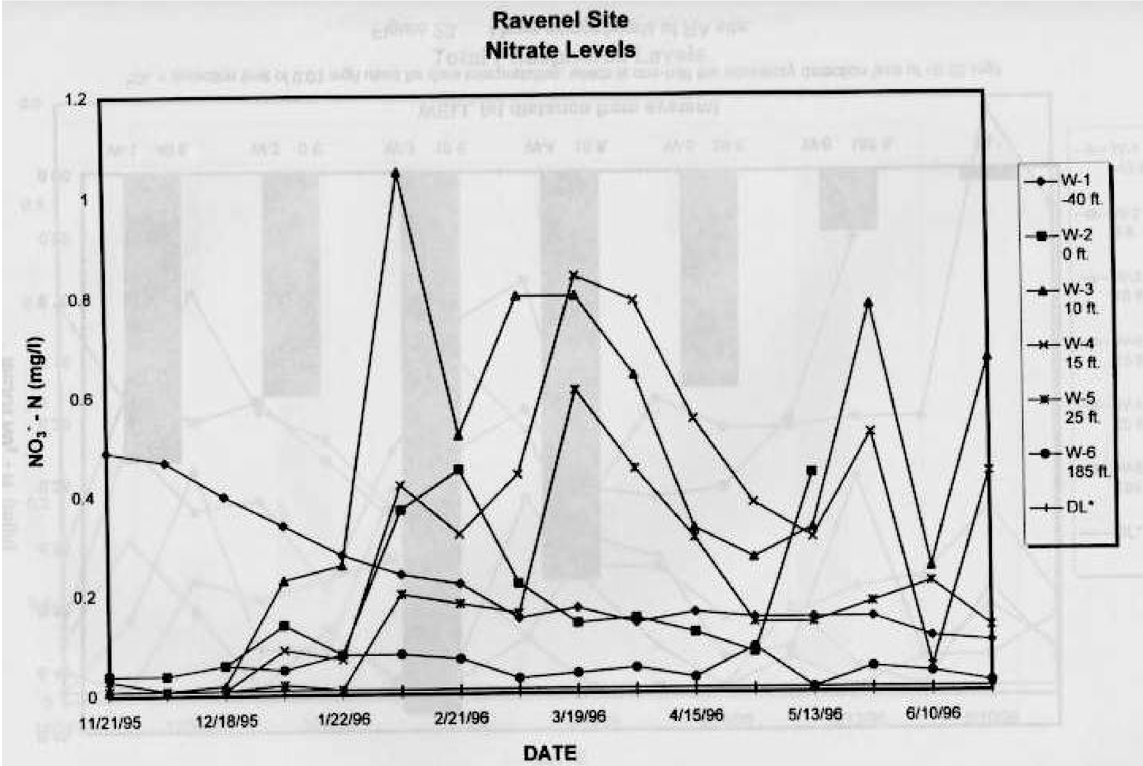
In addition to groundwater samples, several surface water samples were taken from the adjacent ditch when sufficient water was present. Initially, the ditch area immediately downgradient to well W-5 was sampled twice (location WD-2). Later, two additional ditch sampling locations were added for three more sampling events. Location WD-1 was about 100 feet upstream of location WD-2, and location WD-3 was about 180 feet downstream of WD-2, just prior to where the ditch enters the outlet to the river.

Water quality data from the ditch locations as shown in Table 4 can be compared to the data from the wells (Appendix C). The most notable differences can be seen in fecal coliform, ammonium, and total phosphorus levels, all of which were higher in the ditch water. The higher ammonium and phosphorus levels could be attributed to the sediment in the ditch water. The extremely high fecal levels (range of 2 - 50,000 MPN/100 ml) were most likely coming from a dog kennel that is located upstream on a nearby property. This suggests that under these water table conditions, greater impacts to the surface water (i.e., the Wallace River) are coming from the dog kennel and not the septic system. This is not to say that under higher water table conditions, the septic system could not be contributing significant levels of contaminants, namely fecal coliform bacteria, to the surface water as well. This theory would have to be tested when water levels are much higher than they were during this study.



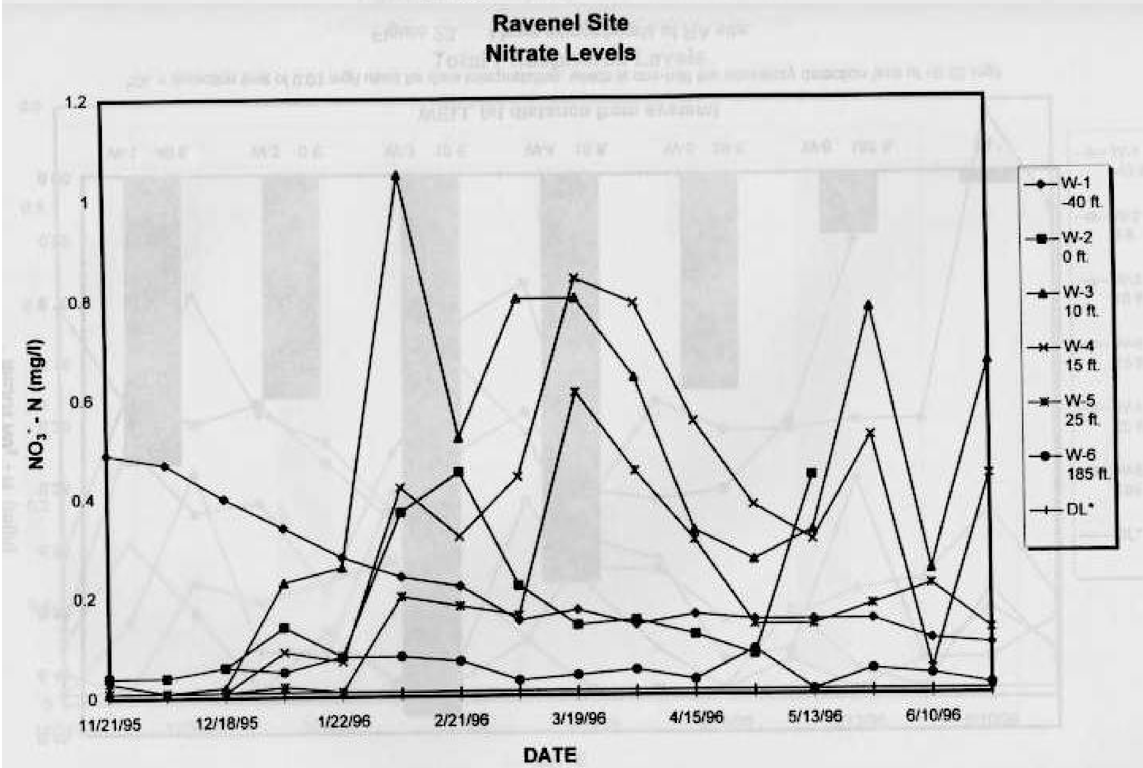
*DL = detection limit of 0.025 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.05 mg/l

Figure 21. Mean ammonium levels at RA site.



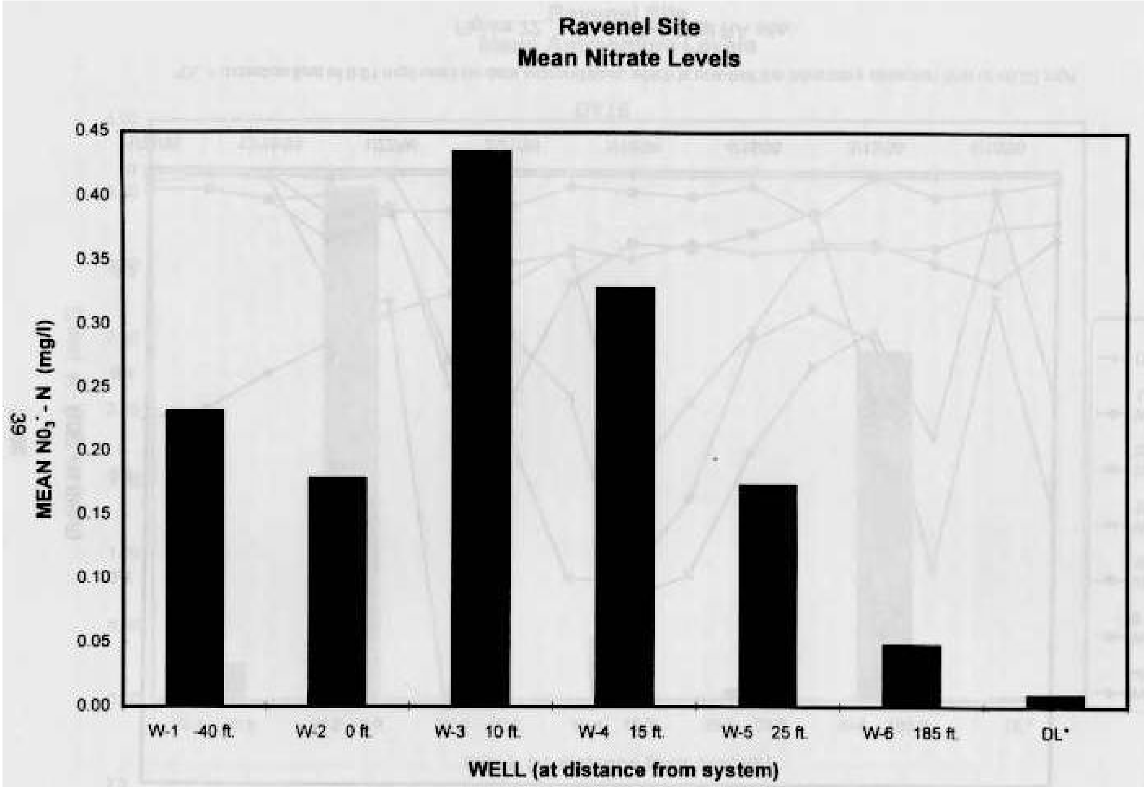
*DL = detection limit of 0.01 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.02 mg/l

Figure 22. Nitrate levels at RA site.



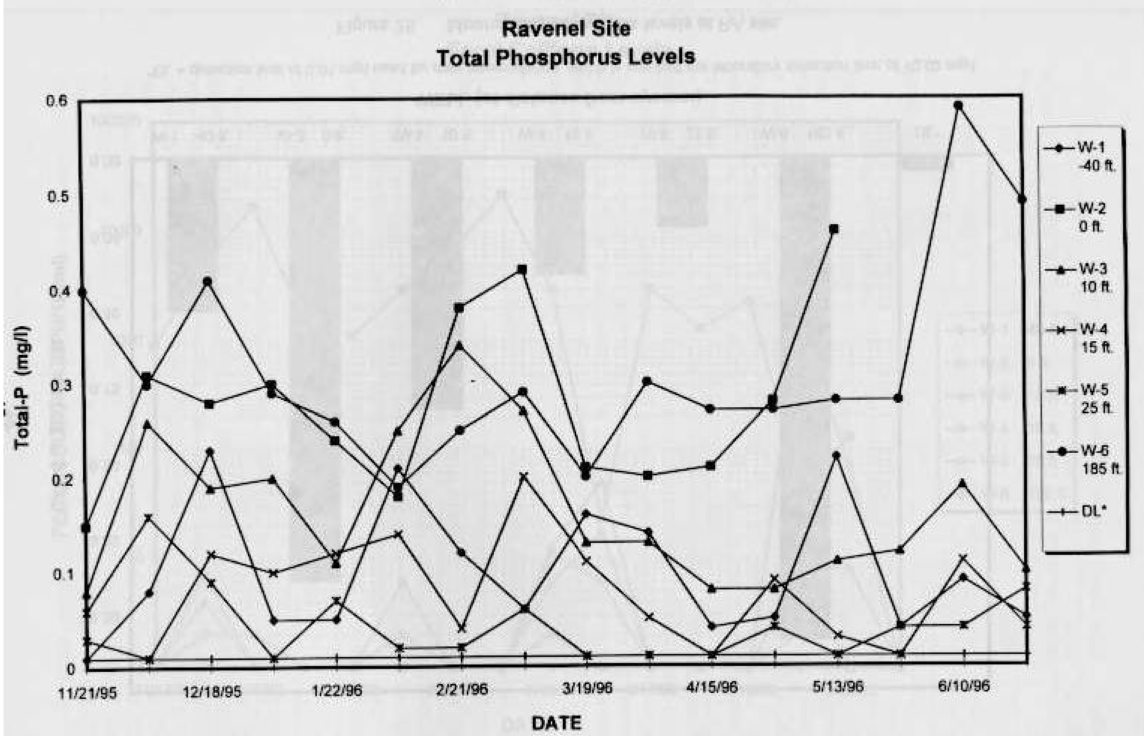
*DL = detection limit of 0.01 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.02 mg/l

Figure 22. Nitrate levels at RA site.



*DL = detection limit of 0.01 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.02 mg/l

Figure 23. Mean nitrate levels at RA site.



*DL = detection limit of 0.01 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.02 mg/l

Figure 24. Total phosphorus levels at RA site.

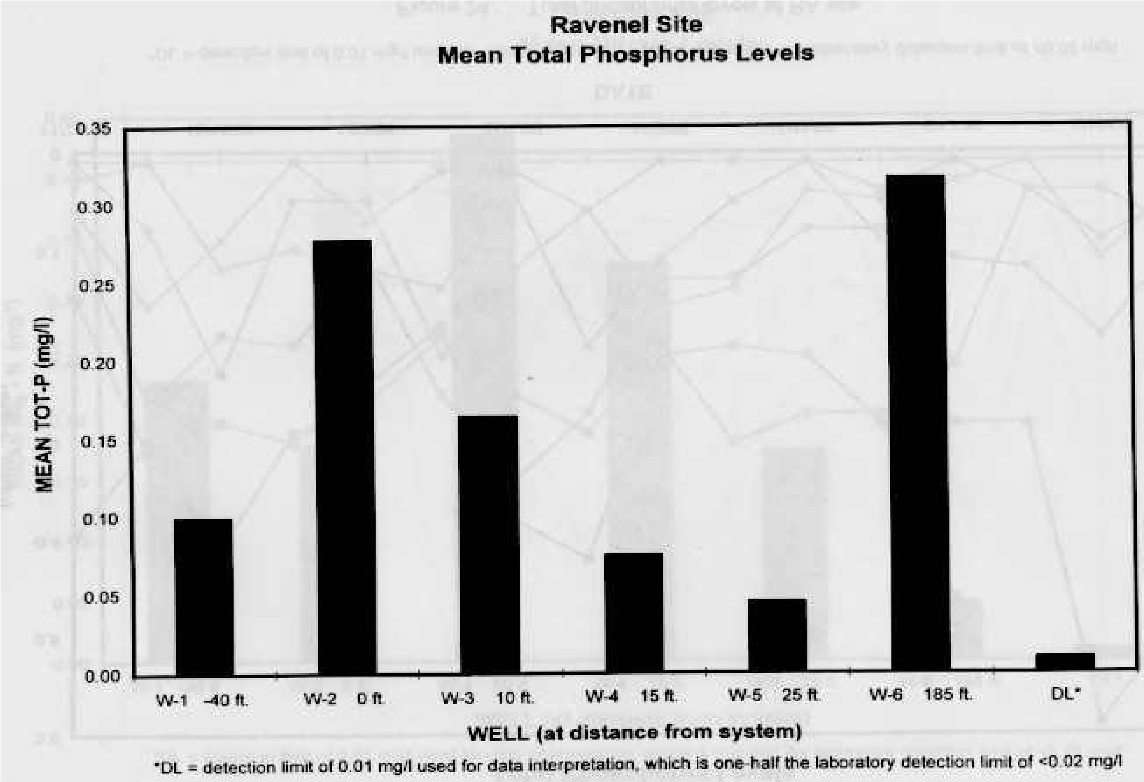


Figure 25. Mean total phosphorus levels at RA site.

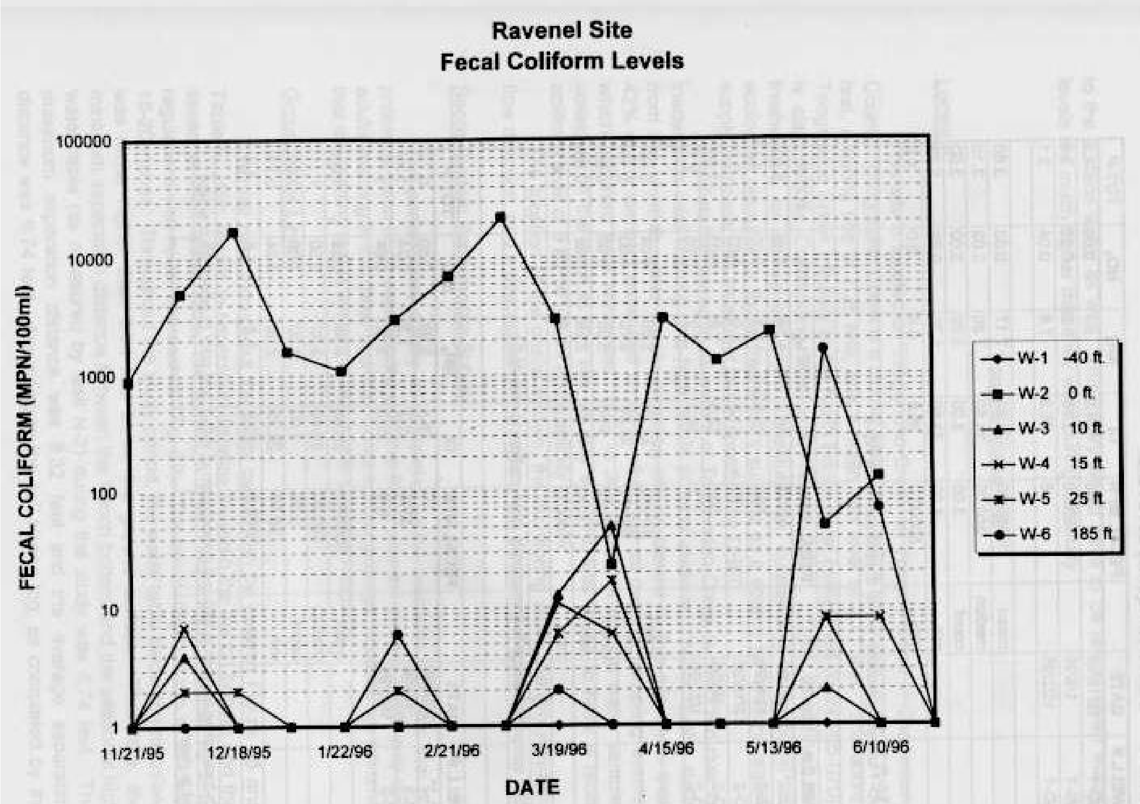


Figure 26. Fecal coliform levels at RA site.

Table 4. Ditch water quality at RA site.

WELL #	DATE		FECAL MPN	Cl	NH_4	NO_3	TOT-P
WD-1*	12/18/95		350	24.6	5.7	0.03	4.9
WD-1	1/9/96		50000	23.6	8.0	0.02	2.8
WD-1	1/22/96		8	26.6	7.8	0.04	3.1
		mean	16786.00	24.93	7.17	0.03	3.60
		median	350.00	24.60	7.80	0.03	3.10
		count	3.00	3.00	3.00	3.00	3.00
		min	8.00	23.60	5.70	0.02	2.80
		max	50000.0	26.6	8.0	0.0	4.9
*WD-1 sampling location is 100 ft. upstream from WD-2							
WELL #	DATE		FECAL MPN	Cl	NH_4	NO_3	TOT-P
WD-2*	11/21/95		1600	16.8	2.26	0.06	0.80
WD-2	12/6/95		500	22.6	5.7	0.02	4.1
WD-2	12/18/95		70	21.9	5.0	0.03	3.5
WD-2	1/9/96		500	23.5	7.8	0.03	1.99
WD-2	1/22/96		2	26.2	7.2	0.05	2.1
		mean	534.40	22.20	5.59	0.04	2.50
		median	500.00	22.60	5.70	0.03	2.10
		count	5.00	5.00	5.00	5.00	5.00
		min	2.00	16.80	2.26	0.02	0.80
		max	1600.0	26.2	7.8	0.1	4.1
*WD-2 sampling location is immediately downgradient to well W-5							
WELL #	DATE		FECAL MPN	Cl	NH_4	NO_3	TOT-P
WD-3*	12/18/95		70	26.4	2.99	0.50	0.73
WD-3	1/9/96		3000	25.2	7.3	0.24	1.39
WD-3	1/22/96		130	28.8	3.92	0.84	1.11
		mean	1066.67	26.80	4.74	0.53	1.08
		median	130.00	26.40	3.92	0.50	1.11
		count	3.00	3.00	3.00	3.00	3.00
		min	70.00	25.20	2.99	0.24	0.73
		max	3000.0	28.8	7.3	0.8	1.4
*WD-3 sampling location is 180 feet downstream of WD-2, just prior to where ditch enters outlet to river							

Yonges Island Site

Location

This site is located on Toogoodoo Creek on Yonges Island in Charleston County. Toogoodoo Creek is a diurnal waterbody with a mean tide range of 6.42 feet, a spring tide of 7.25 feet, and a mean tide level of 3.41 feet. The entire Toogoodoo Creek tributary to the North Edisto River (watershed 03050205-070) is classified as Outstanding Resource Waters (ORW). ORW is defined as freshwaters or saltwaters which constitute an outstanding recreational or ecological resource or those freshwaters suitable as a source for drinking water supply purposes with treatment levels specified by DHEC.

Shellfish harvesting in all waters of Toogoodoo Creek is restricted due to inadequate tidal flushing and high levels of fecal coliform. Water quality data from the shellfish water quality sampling station closest to this site show that 42% of the samples exceeded an MPN of 43/100 ml over 19 sampling events which occurred from November 1992, to July 1995. A surface water sample collected off the dock at this site on July 9, 1996, was found to have a fecal coliform level of 8 MPN/100 ml and a salinity of 24%.

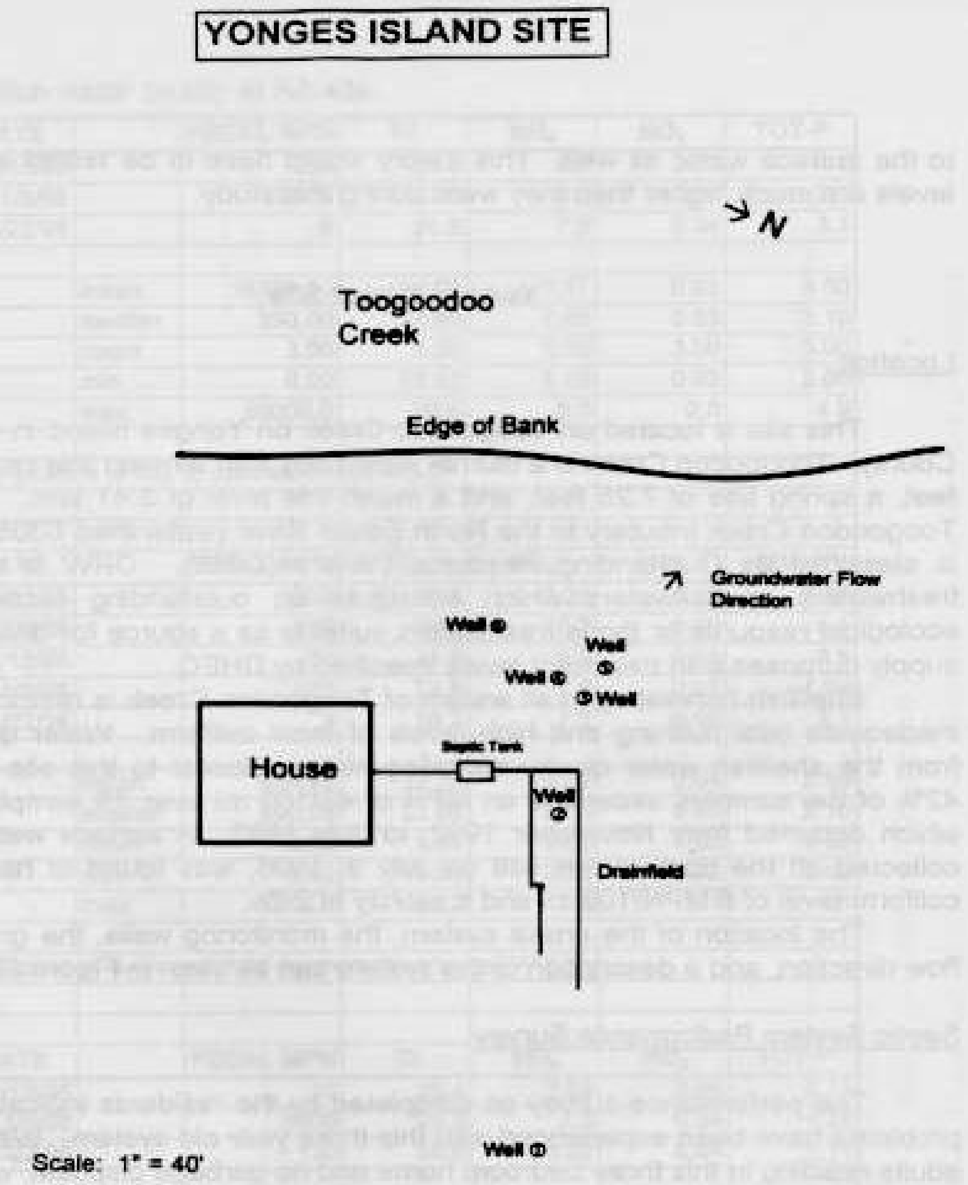
The location of the onsite system, the monitoring wells, the groundwater flow direction, and a description of the system can be seen in Figure 27.

Septic System Performance Survey

The performance survey as completed by the residents indicates that no problems have been experienced with this three year old system. With only two adults residing in this three bedroom home and no garbage disposal, we assume that the loading to this system is well below its design capacity.

Groundwater Levels

Rainfall data throughout the study period can be seen in Figure 28 and Table 5. With regard to separation distance between the trench bottom and the seasonal high water table, the minimum 6-inch separation required by S.C. regulations was never approached (Fig. 29). The trench depth at the YI site was 18-20 inches. Throughout the study period, the water table below the drainfield was never higher than 6.34 feet below the ground surface. Therefore, the minimum separation distance between the trench bottom and the seasonal high water table (as measured by well N-2) during the study was 4.74 feet. The maximum separation distance was 8.32 feet and the average separation distance was 6.74 feet. According to the soil boring log, as completed by the Charleston County Health Department in 1996, the seasonal high water table in the vicinity of well N-2 could potentially be as high as 36 inches (Appendix D).



YONGES ISLAND SITE SYSTEM DESCRIPTION

SYSTEM TYPE:	Single family residence, 3 bedroom
SYSTEM CATEGORY:	Modified conventional, shallow placement
DHEC SYSTEM CODE:	362-210
DATE OF INSTALLATION:	November 1993
DESIGN FLOW:	360 GPD
DESIGN SOIL LOADING RATE:	0.9 GPD/FT^2
TANK CAPACITY:	1000 gallon
DISTRIBUTION:	Gravity
TRENCH DEPTH:	18-20 inches installed
ROCK DEPTH:	9 + inches

Figure 27. Yonges Island site map.

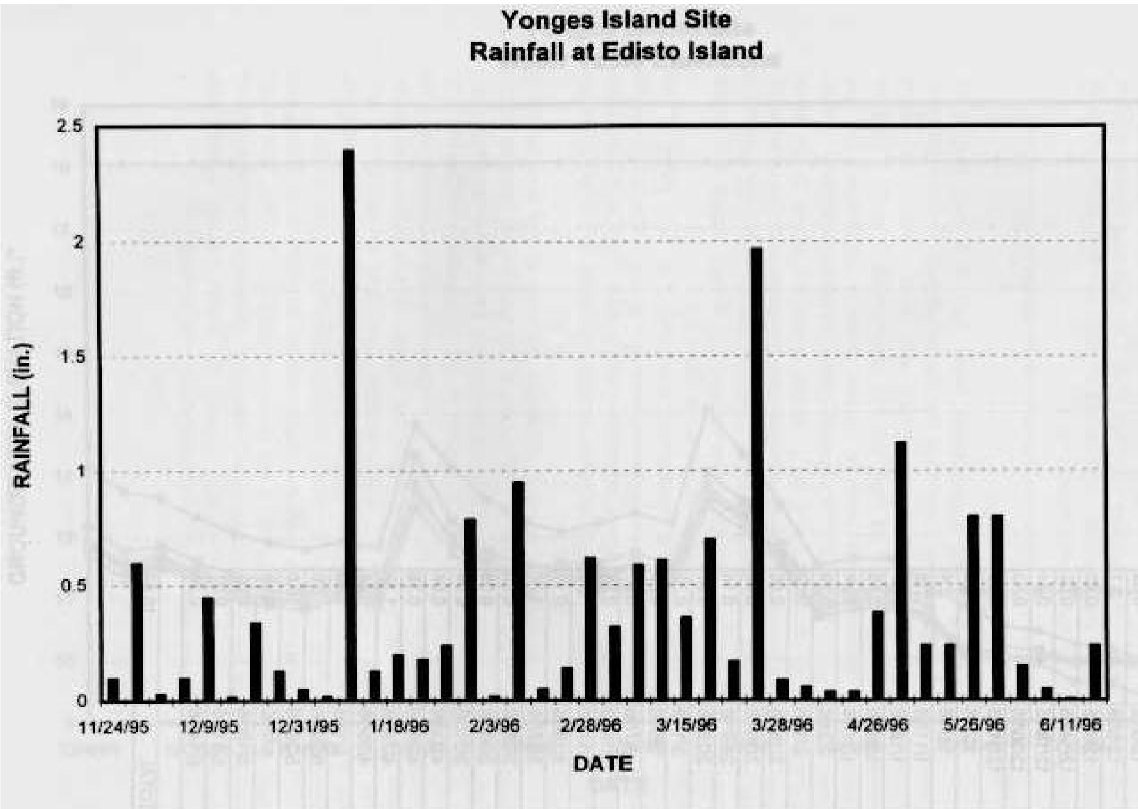


Figure 28. Rainfall at station closest to YI site.

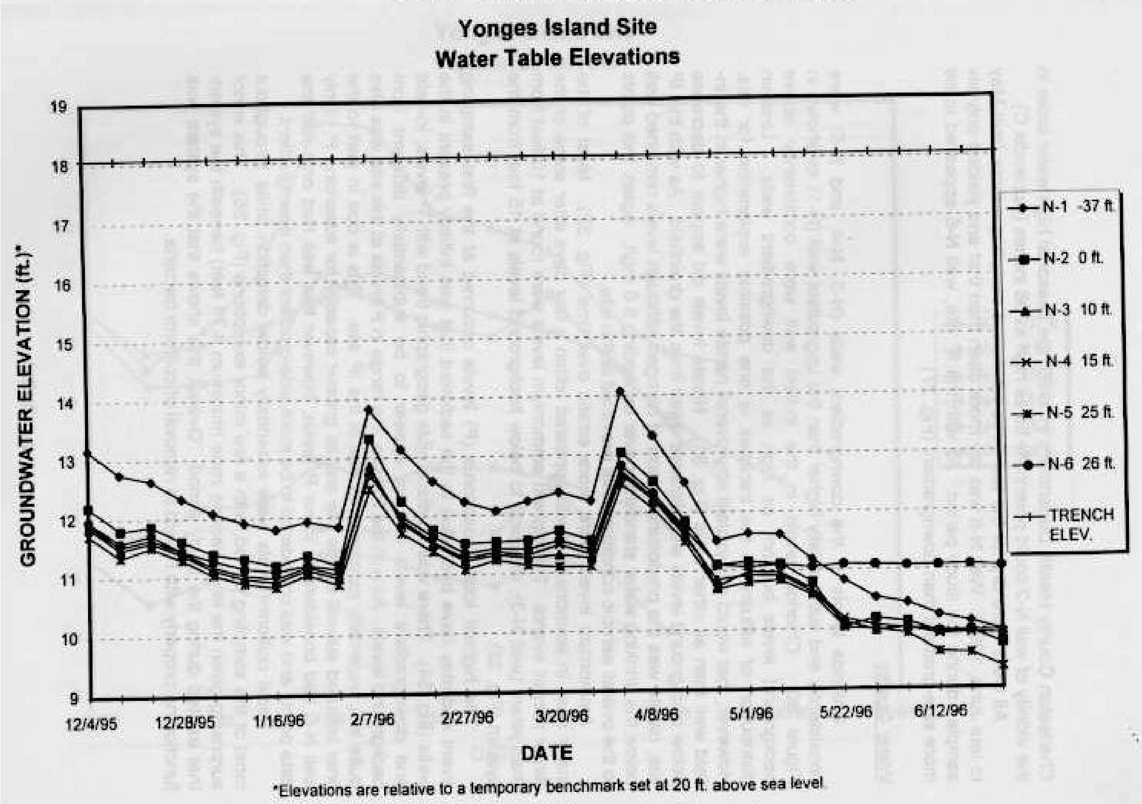


Figure 29. Water table elevations at YI site.

Table 5. Rainfall data for station closest to YI site. (Edisto Island Weather Station)

DATE	RAINFALL (in.)
11/24/95	0.1
11/28/95	0.6
12/5/95	0.03
12/6/95	0.1
12/9/95	0.45
12/14/95	0.02
12/18/95	0.34
12/30/95	0.13
12/31/95	0.05
1/2/96	0.02
1/6/96	2.4
1/11/96	0.13
1/18/96	0.2
1/26/96	0.18
1/31/96	0.24
2/2/96	0.79
2/3/96	0.02
2/15/96	0.95
2/16/96	0.05
2/19/96	0.14
2/28/96	0.62
3/1/96	0.32
3/6/96	0.59
3/7/96	0.61
3/15/96	0.36
3/17/96	0.7
3/18/96	0.17
3/27/96	1.97
3/28/96	0.09
3/30/96	0.06
3/31/96	0.04
4/23/96	0.04
4/26/96	0.38
4/29/96	1.12
4/30/96	0.24
5/1/96	0.24
5/26/96	0.8
5/28/96	0.8
6/9/96	0.15
6/10/96	0.05
6/11/96	0.01
6/14/96	0.24
TOTAL	16.54

All wells were dry for the last three attempted sampling events (mid-May to late June, 1996). Well N-6 was dry more often than that and yielded only six samples during the study period. As with the IP site, well N-6 appeared to be more side-gradient than downgradient (Fig. 27).

Water Quality

Chloride levels in the downgradient wells (N-3, N-4, and N-5) were consistently and substantially higher than the upgradient well (N-1) as shown in Figure 30. Chloride levels in the in-field well were consistently above background levels but not as high as the downgradient wells. Uneven distribution of effluent in the trenches is one possible explanation for this. However, that would not explain why overall nitrate levels were higher in the in-field well than all other wells (Fig. 31). Nitrate levels did appear to decrease below background levels with distance away from the drainfield. As with the IP site, nitrate was the predominant form of nitrogen although levels remained well below the drinking water standard, never exceeding 5.0 mg/l. Again, this points to the overall aerobic conditions that prevailed at this site.

Ammonium levels were more erratic over time (Fig. 32). Most of the major rises in ammonium levels appeared within a few days after some of the larger rainfall events. The highest ammonium levels were found at 10 feet from the system (well N-3), dropping to below background levels at 15 feet from the system (Fig. 33).

The highest total phosphorus (P) levels occurred at the first sampling event and may have been due to the sediment that was initially present in the wells (Fig. 34). There was no discernible geographic trend with P levels; in-field and downgradient levels did not appear to be substantially different from background levels. As with the RA site, the range in P levels at this site was also quite low, especially compared to that at the IP site. This is due in part to the finer textured subsoil at this site and its greater capacity for adsorbing P. Only well N-6 had considerably lower P levels, however this well had only half the data points and was considered to be more side-gradient than downgradient.

Fecal coliform levels were essentially below detection limits throughout most of the sampling period, with a few minor exceptions (Fig. 35). This is not surprising given the large vadose zone (minimum 4.74 feet) beneath the system that existed during the study period. Overall, this shows that the system was functioning properly with regard to removal of coliform bacteria.

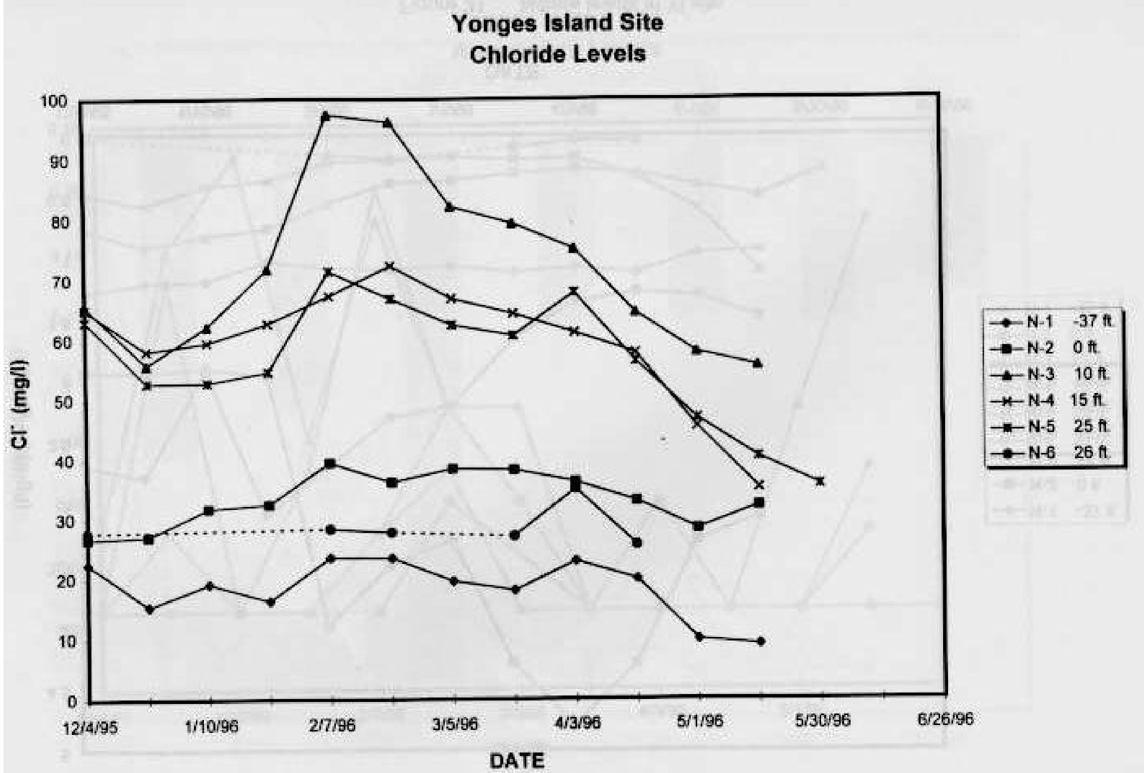


Figure 30. Chloride levels at YI site.

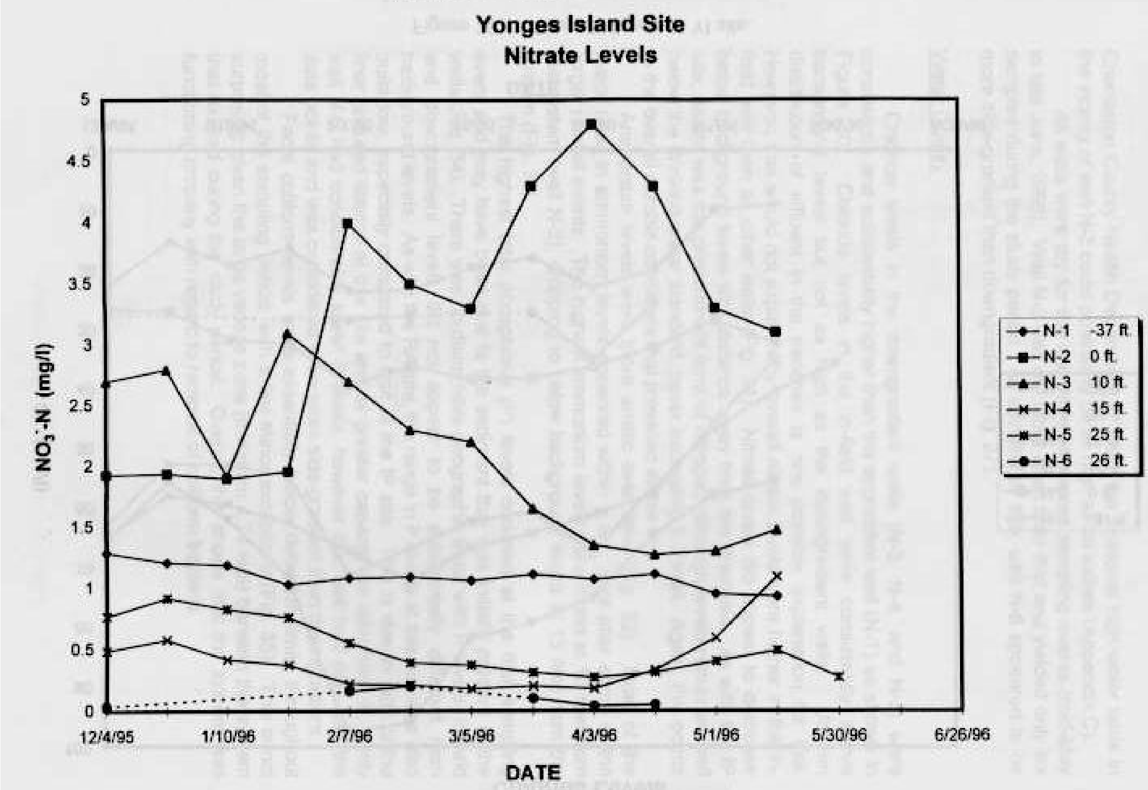


Figure 31. Nitrate levels at YI site.

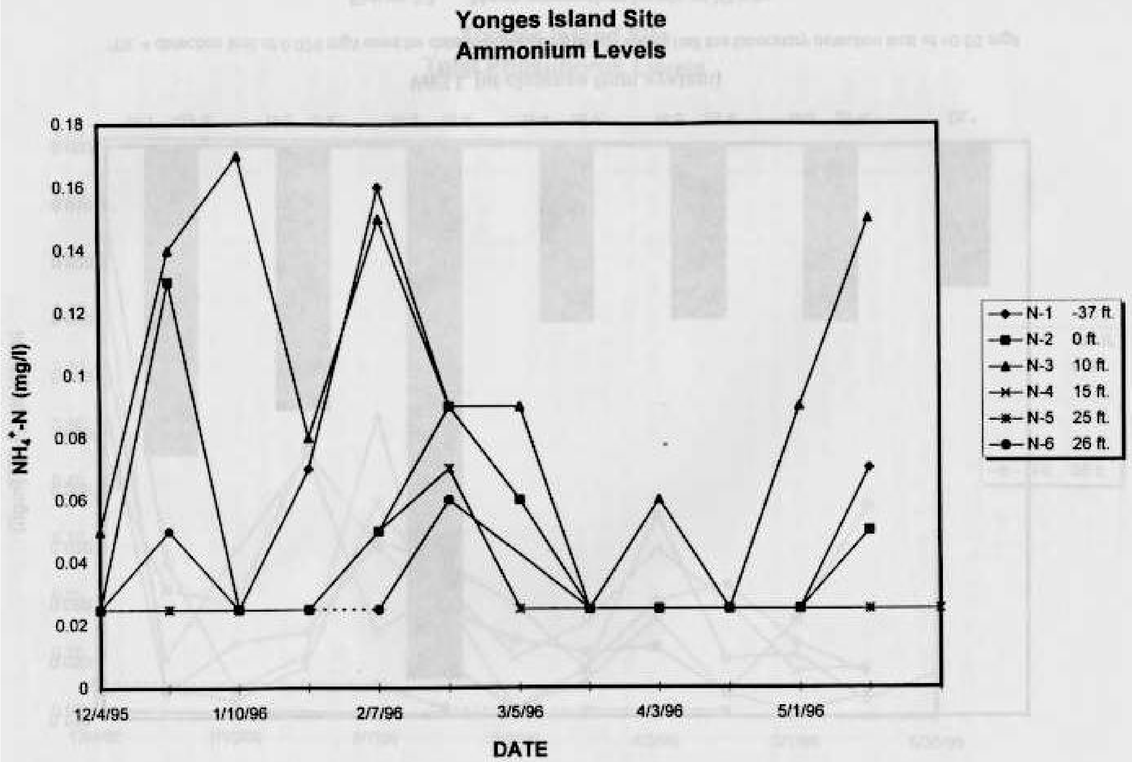


Figure 32. Ammonium levels at YI site.

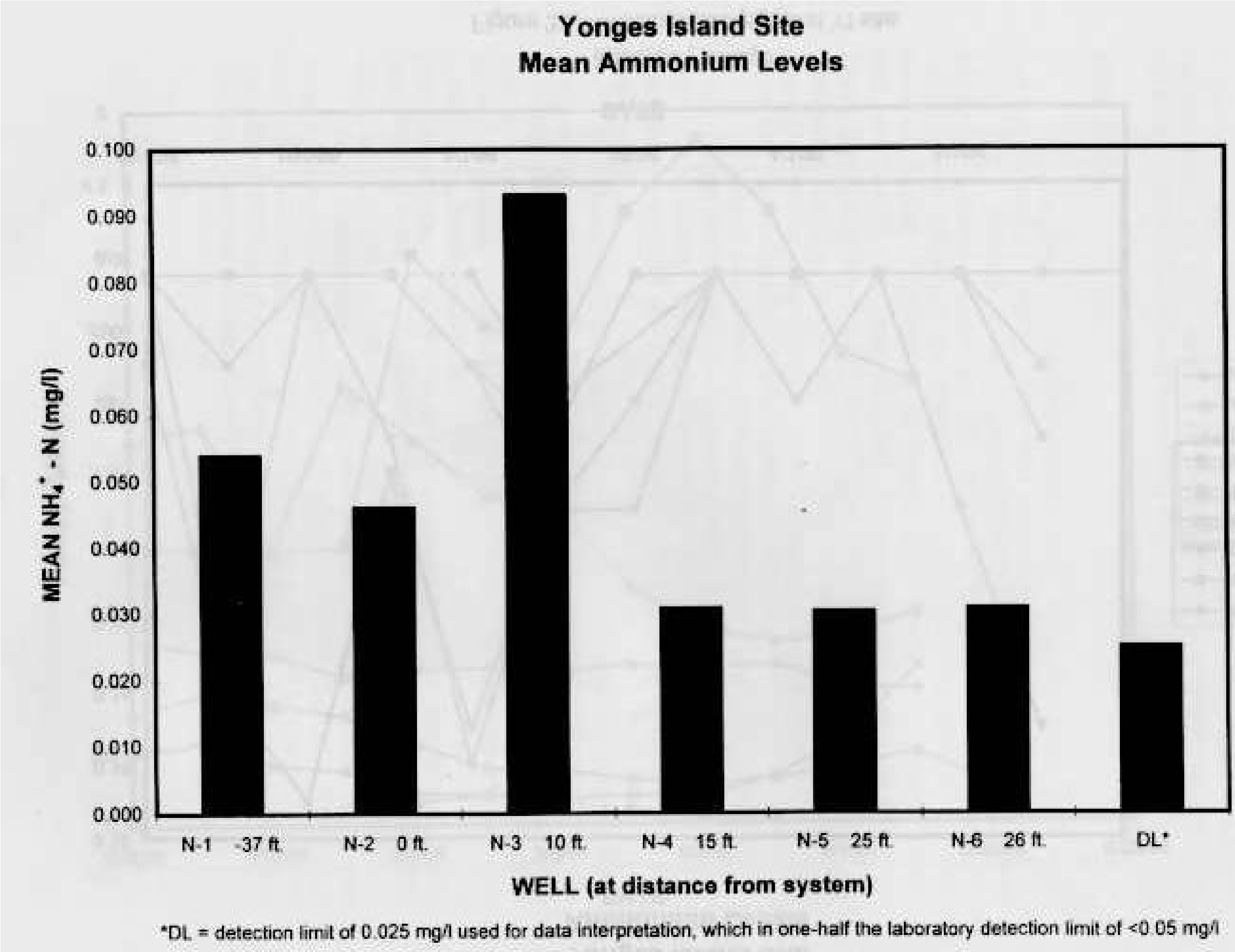


Figure 33. Mean ammonium levels at YI site.

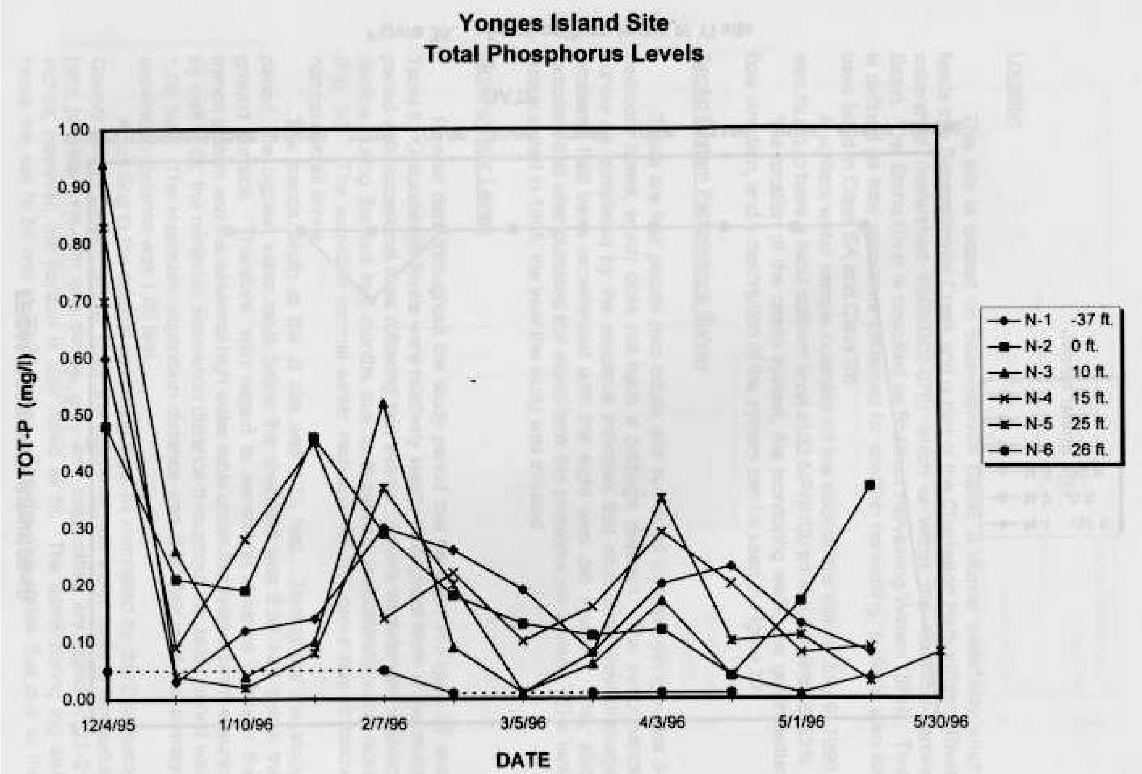


Figure 34. Total phosphorus levels at YI site.

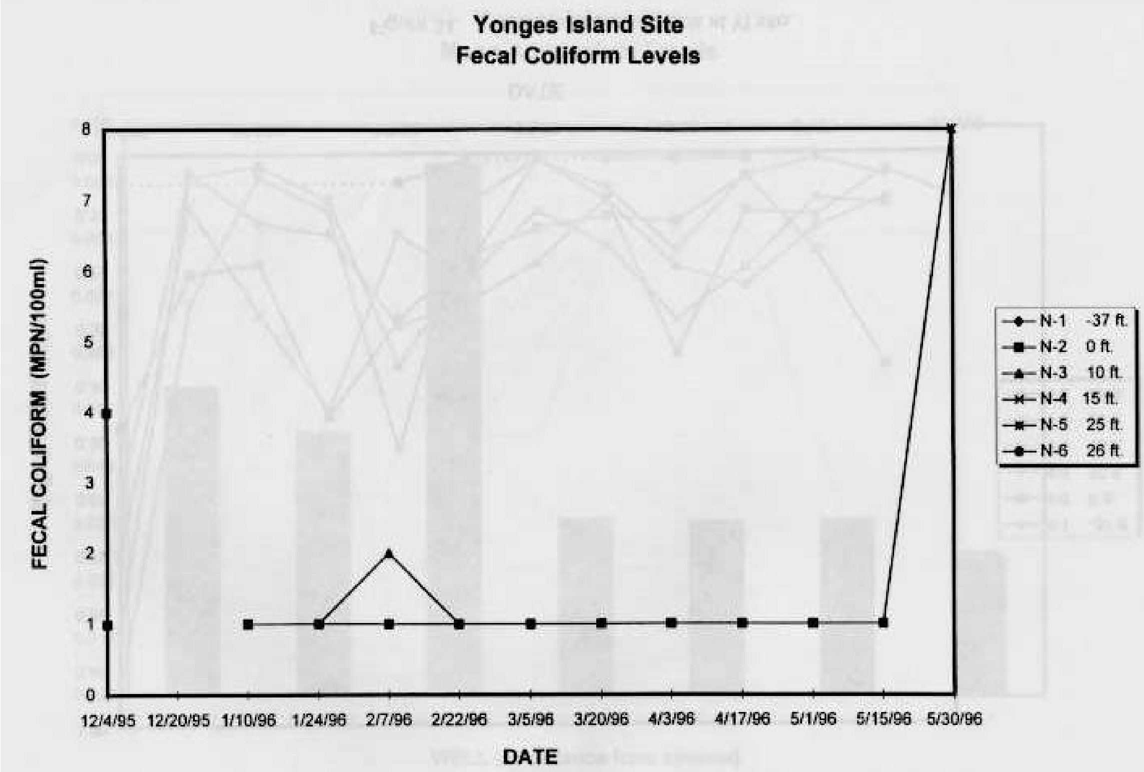


Figure 35. Fecal coliform levels at YI site.

James Island Site

Location

This site is located on Secessionville Canal, a diurnal waterbody which feeds into Secessionville Creek and is part of the Charleston Harbor/Stono River watershed (watershed 03050202-070) which is within the Catawba-Santee Basin. The Stono River is classified as Shellfish Harvesting Waters (SFH). This is defined as tidal saltwaters protected for shellfish harvesting; suitable also for uses listed in Class SA and Class SB.

A surface water sample collected off the dock at this site on July 9, 1996, was found to have a fecal coliform level of 33 MPN/100 ml and a salinity of 33%.

The location of the onsite system, the monitoring wells, the groundwater flow direction, and a description of the system can be seen in Figure 36.

Septic System Performance Survey

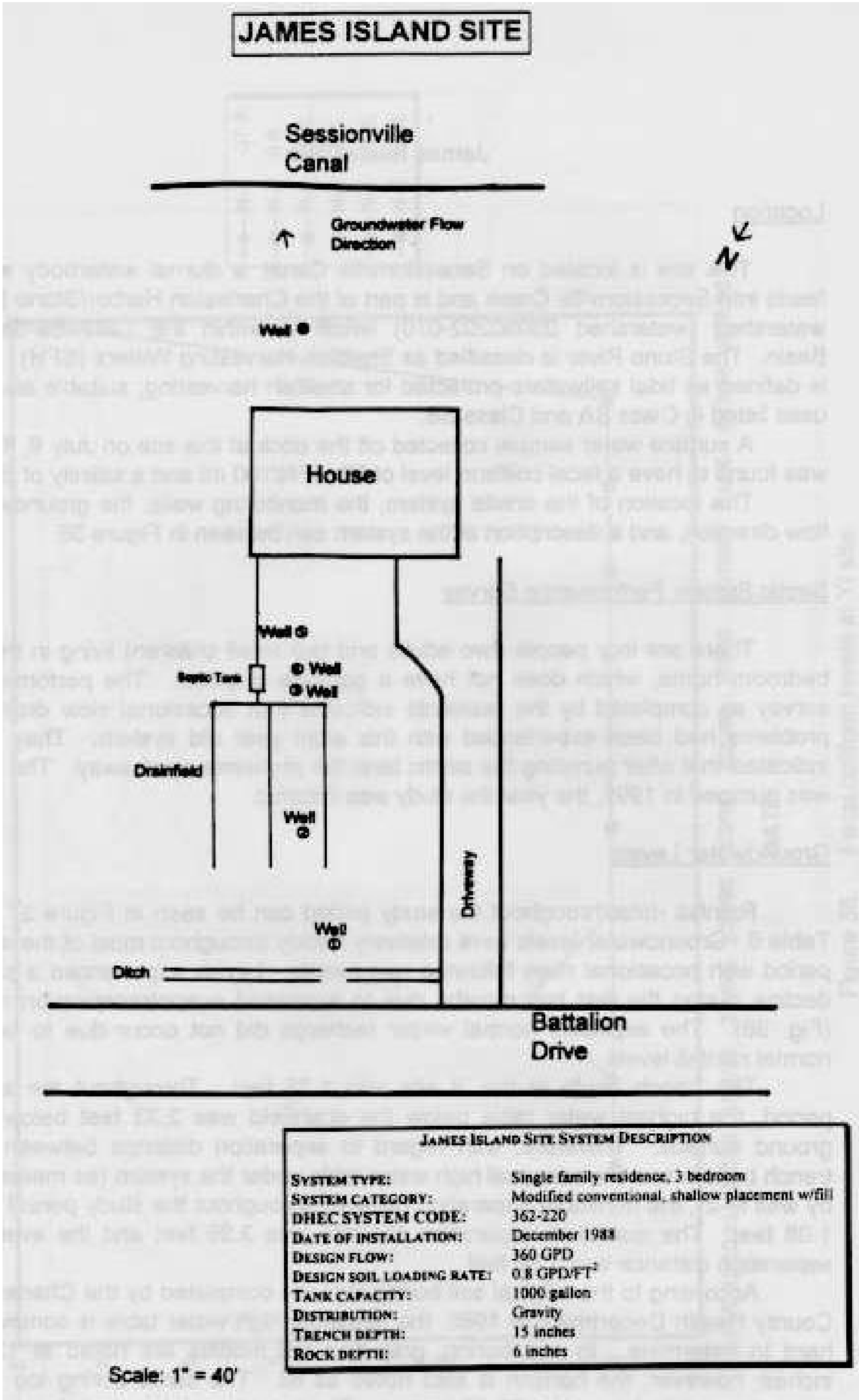
There are four people (two adults and two small children) living in this 3-bedroom home, which does not have a garbage disposal. The performance survey as completed by the residents indicates that occasional slow drainage problems had been experienced with this eight year old system. They also indicated that after pumping the septic tank the problems went away. The tank was pumped in 1995, the year the study was initiated.

Groundwater Levels

Rainfall data throughout the study period can be seen in Figure 37 and Table 6. Groundwater levels were relatively steady throughout most of the study period with occasional rises following rain events. Levels experienced a sharp decline during the last two months due to increased evapotranspiration rates (Fig. 38). The expected normal winter recharge did not occur due to below normal rainfall levels.

The trench depth at the JI site was 1.25 feet. Throughout the study period, the highest water table below the drainfield was 2.33 feet below the ground surface. Therefore, with regard to separation distance between the trench bottom and the seasonal high water table under the system (as measured by well M-2), the minimum separation distance throughout the study period was 1.08 feet. The maximum separation distance was 3.26 feet and the average separation distance was 1.96 feet.

According to the original soil boring logs, as completed by the Charleston County Health Department in 1986, the seasonal high water table is somewhat hard to determine. In one boring, gray and red mottles are noted at 12-21 inches; however, the horizon is also noted as fill. The same boring log also notes the soil to be wet at 29-36 inches. The log also states that due to the original permit issuance date of 1979, the permit had to be honored even though the regulations and soil evaluation techniques had been changed since then (Appendix D).



JAMES ISLAND SITE SYSTEM DESCRIPTION

SYSTEM TYPE:	Single family residence, 3 bedroom
SYSTEM CATEGORY:	Modified conventional, shallow placement w/fill
DHEC SYSTEM CODE:	362-220
DATE OF INSTALLATION:	December 1988
DESIGN FLOW:	360 GPD
DESIGN SOIL LOADING RATE:	0.8 GPD/FT^2
TANK CAPACITY:	1000 gallon
DISTRIBUTION:	Gravity
TRENCH DEPTH:	15 inches
ROCK DEPTH:	6 inches

Figure 36. James Island site map.

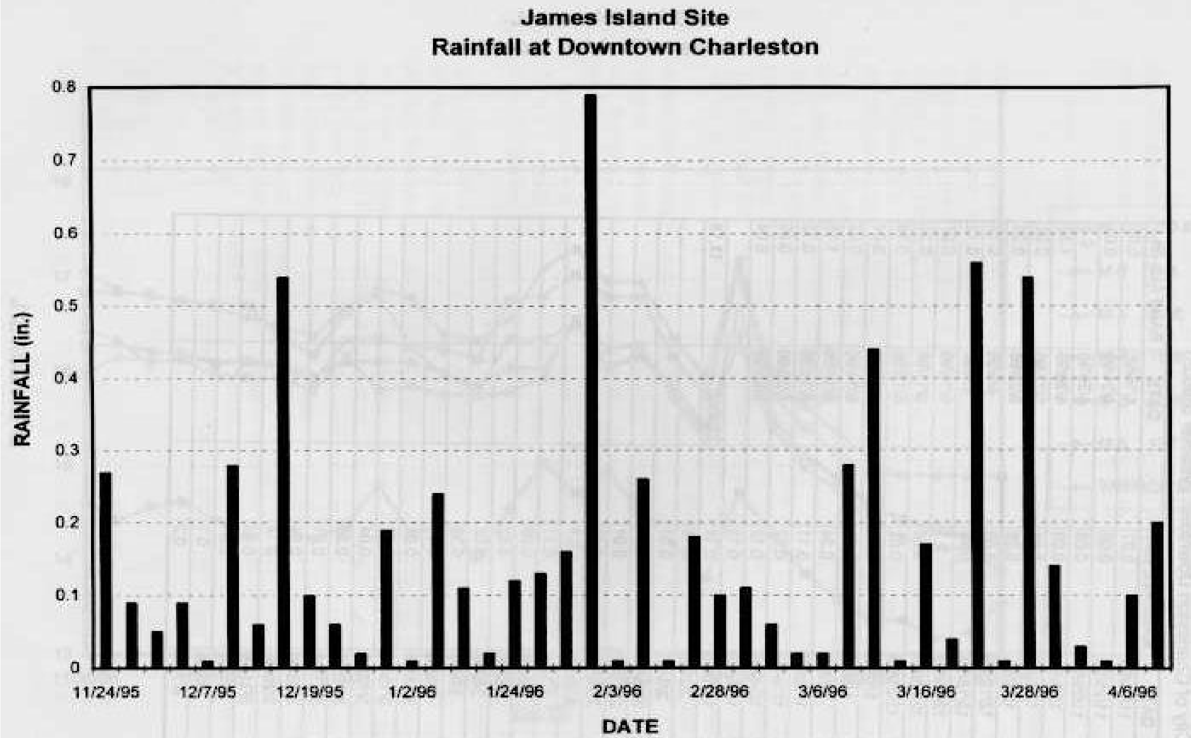


Figure 37. Rainfall at station closest to JI site.

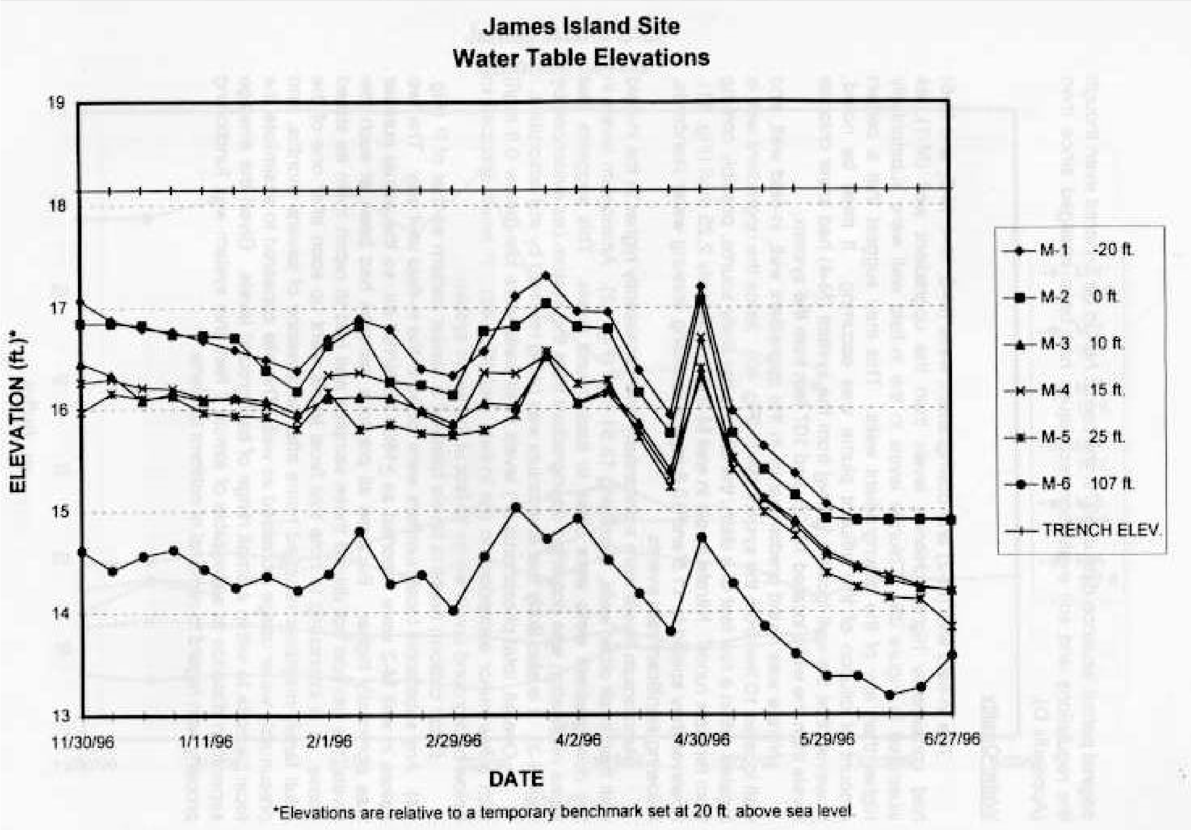


Figure 38. Water table elevations at JI site.

Table 6. Rainfall data for station closest to JI site. (City of Charleston Downtown Weather Station)

DATE	RAINFALL (in.)	DATE	RAINFALL (in.)
11/24/95	0.27	4/16/96	0.08
11/25/95	0.09	4/24/96	0.03
11/29/95	0.05	4/26/96	0.5
12/6/95	0.09	4/30/96	1.39
12/7/95	0.01	5/27/96	0.02
12/9/95	0.28	5/28/96	0.25
12/10/95	0.06	6/5/96	0.12
12/18/95	0.54	6/9/96	0.12
12/19/95	0.1	6/10/96	0.07
12/30/95	0.06	6/11/96	0.32
12/31/95	0.02	6/12/96	0.16
1/1/96	0.19	6/13/96	0.04
1/2/96	0.01	6/14/96	0.02
1/7/96	0.24	6/16/96	1.18
1/12/96	0.11	6/19/96	0.12
1/19/96	0.02	6/20/96	0.06
1/24/96	0.12	6/25/96	0.04
1/27/96	0.13		
1/31/96	0.16	**TOTAL**	11.16
2/2/96	0.79		
2/3/96	0.01		
2/15/96	0.26		
2/16/96	0.01		
2/20/96	0.18		
2/28/96	0.1		
3/1/96	0.11		
3/2/96	0.06		
3/5/96	0.02		
3/6/96	0.02		
3/7/96	0.28		
3/8/96	0.44		
3/15/96	0.01		
3/16/96	0.17		
3/17/96	0.04		
3/18/96	0.56		
3/27/96	0.01		
3/28/96	0.54		
3/29/96	0.14		
3/31/96	0.03		
4/1/96	0.01		
4/6/96	0.1		
4/7/96	0.2		

Water Quality

The in-field well (M-2) and downgradient wells (M-3, M-4, M-5, and M-6) had consistently higher chloride levels than the upgradient well (M-1), as illustrated in Figure 39. Chloride levels in the in-field well were substantially higher than any of the downgradient wells. This may suggest that a certain amount of dilution of the effluent plume was occurring. It must be noted, however, that the well located 16 feet from the system (M-4) had lower chloride levels than the wells located 10, 25, and 107 feet from the system.

Nitrate was found predominantly in the upgradient well, in-field well, and well located 10 feet from the system (M-3) (Fig. 40). Since the upgradient well is located within a few feet of a ditch, the ditch is the likely source, possibly coming from fertilizer runoff. Nitrate levels in well M-3 averaged only 2.25 mg/l (Fig. 41), however they spiked to 11.5 and 10.6 mg/l, exceeding drinking water standards, following significant rain events.

Ammonium levels were substantially and consistently higher in the in-field well than in all other wells, averaging 13.51 mg/l (Fig. 42). Ammonium levels in the downgradient wells were close to background levels. This suggests that some nitrification was occurring downgradient from the system (as evidenced by well M-3). It is also likely that ammonium was being retained by soil adsorption.

Overall, total phosphorus (P) levels in all wells were low (below 0.8 mg/l) with a few minor exceptions in the in-field well (Fig. 43). P levels dropped to below background levels within 10 feet of the septic system.

Fecal coliform bacteria levels followed a similar pattern as that of P (Fig. 44). Any substantial fecal numbers were found in the in-field well only. The two spikes in well M-2 were reported as $\geq$1600 MPN/100 ml, so the actual number was potentially higher. Because all previous samples had been at such low levels, the lab had not diluted these samples and had to report them as stated above. It is interesting to note that fecal levels went up soon after one of the adult family members returned home after an absence of several months, and presumably water usage increased as well. The site appeared to assimilate the fecal bacteria to within a small range of background levels. Given the average separation distance to water table of almost 2 feet, this system was functioning properly with regard to removal of coliform bacteria.

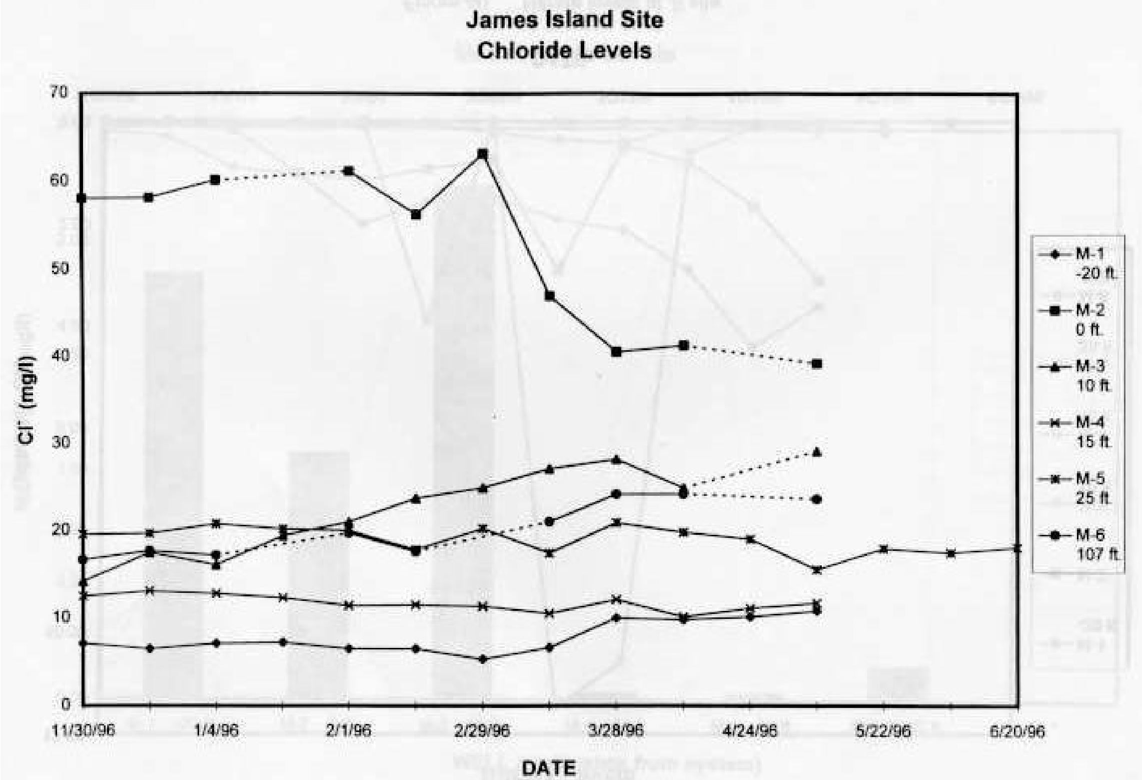


Figure 39. Chloride levels at JI site.

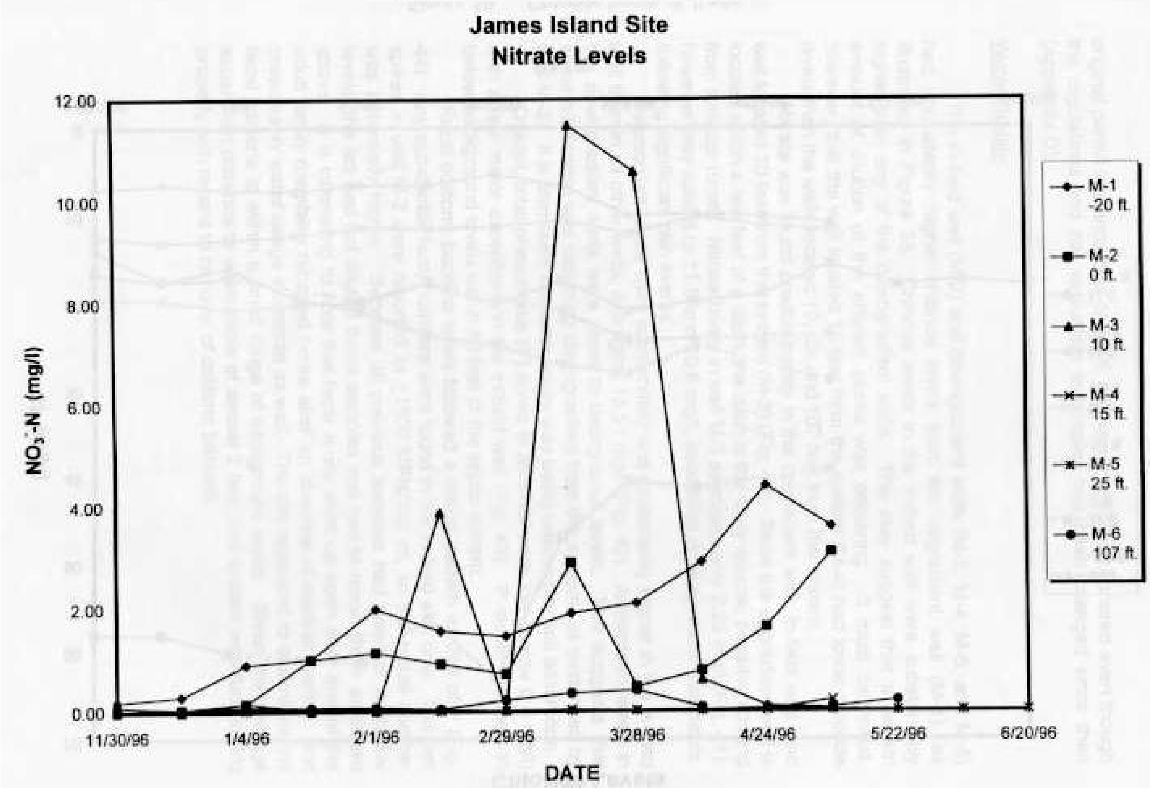
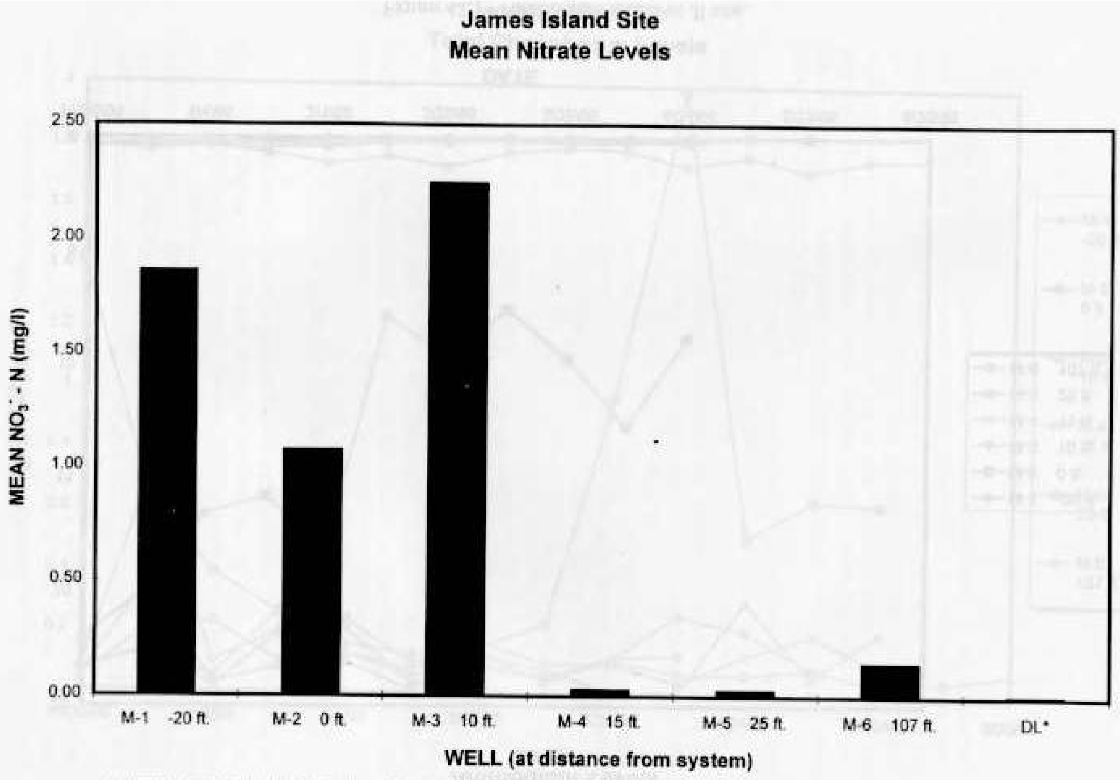


Figure 40. Nitrate levels at JI site.



*DL = detection limit of 0.01 mg/l used for data interpretation, which is one-half the laboratory detection limit of <0.02 mg/l

Figure 41. Mean nitrate levels at JI site.

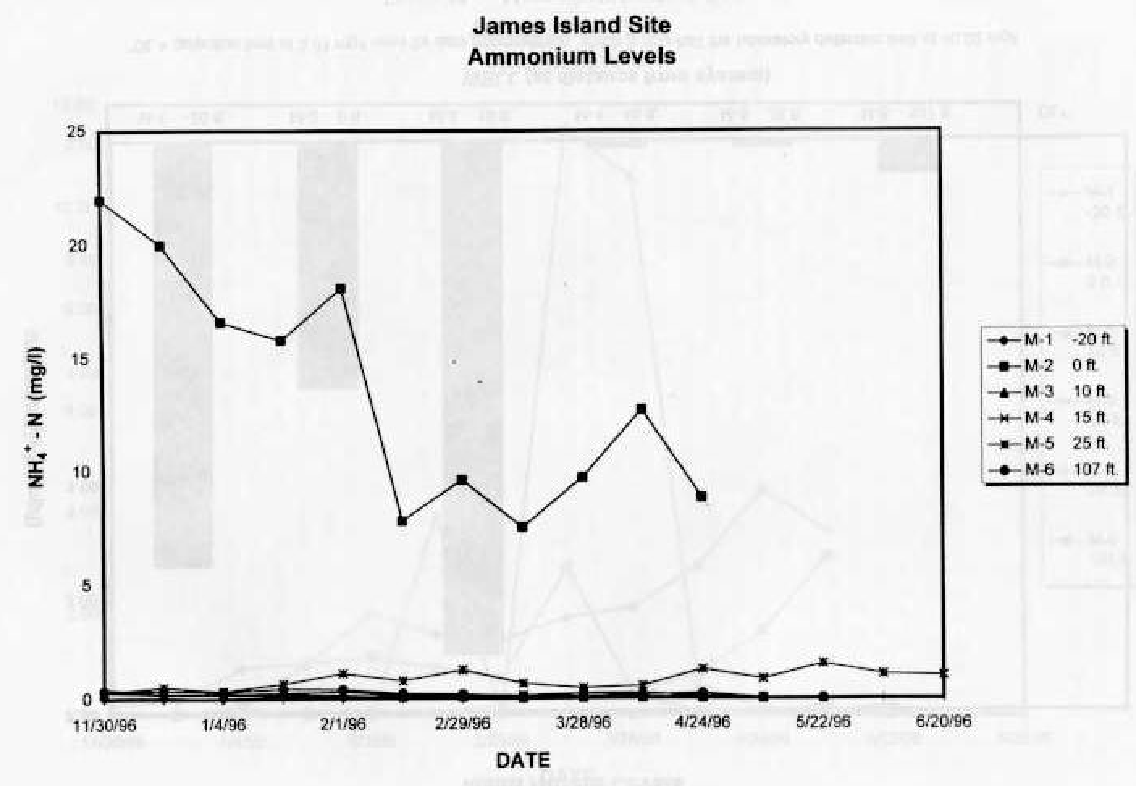


Figure 42. Ammonium levels at JI site.

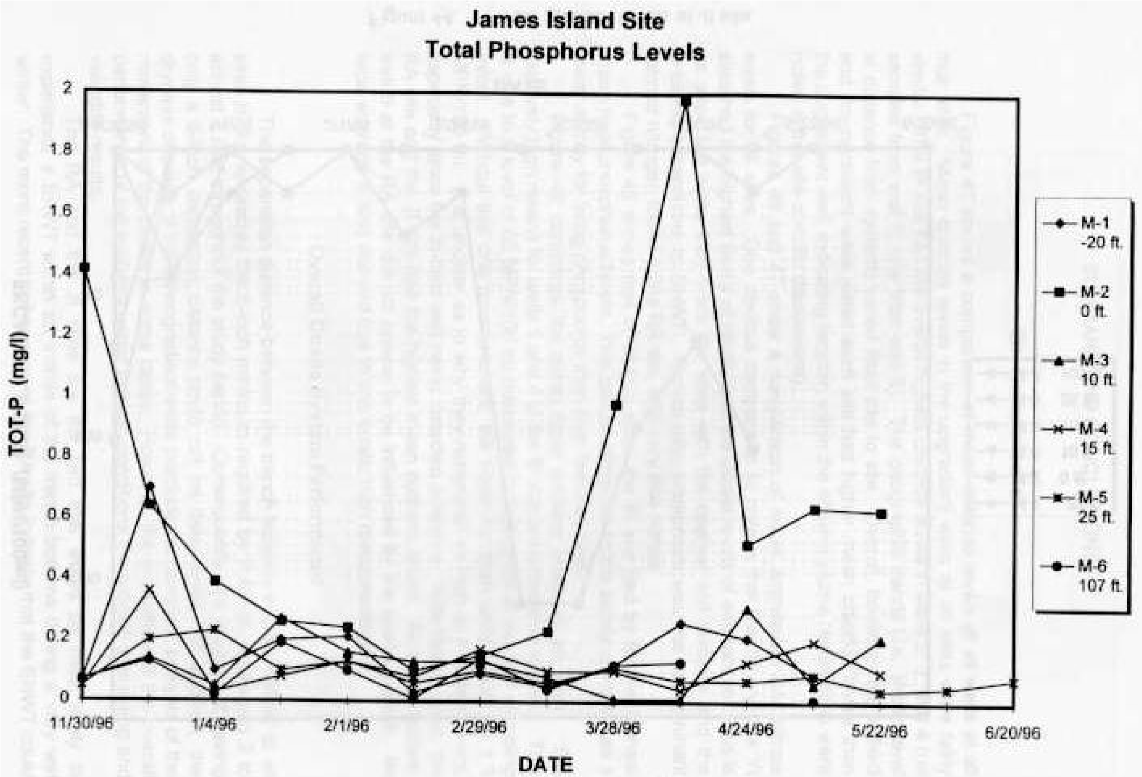


Figure 43. Total phosphorus levels at JI site.

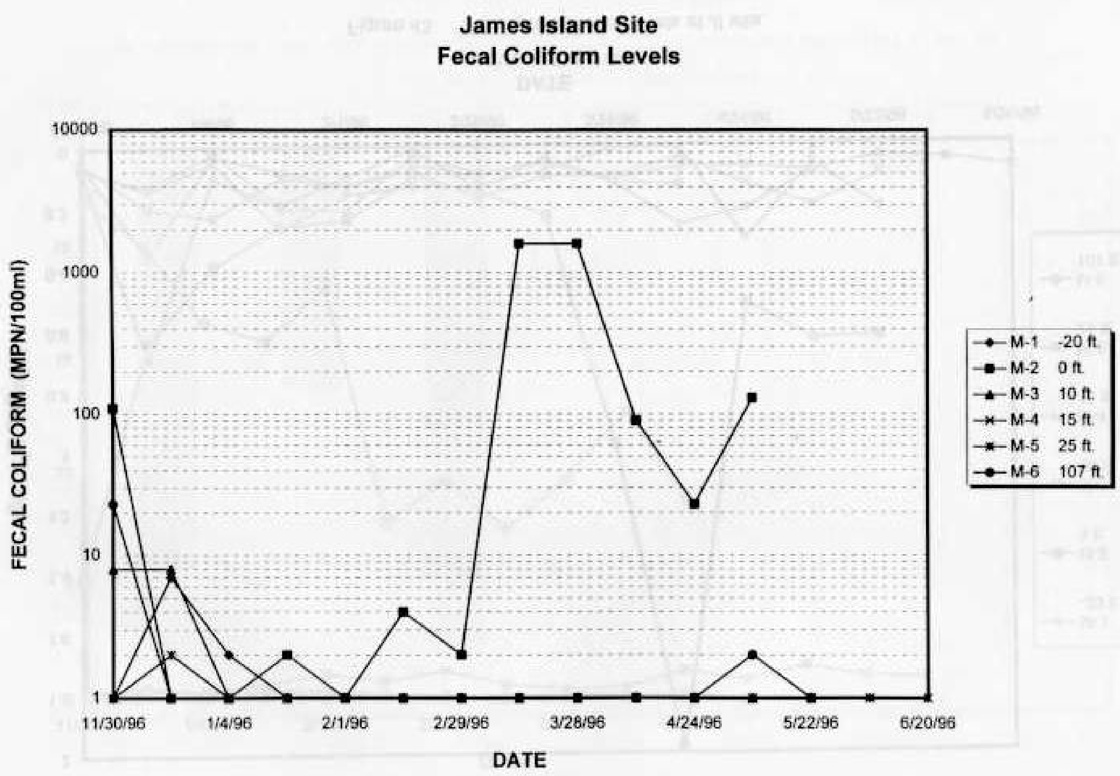


Figure 44. Fecal coliform levels at JI site.

SUMMARY AND CONCLUSIONS

Site Comparisons

Figure 45 shows a comparison of mean chloride levels of all wells at all four sites. Mean chloride levels in the upgradient wells at all sites were fairly similar. The IP site had the overall highest chloride levels in wells 2, 3, and 4 (no samples from well 5; one from well 6). The geographic trends (i.e., mean level at distance from system) varied from site to site. Overall, however, the in-field and downgradient wells within each site had higher mean chloride levels than the upgradient well, indicating location within the effluent plume (exceptions were noted in the site-specific discussions).

Figures 46 and 47 show a comparison of mean ammonium and nitrate levels for all sites. One obvious comparison to note is that the IP and the YI sites had the highest levels of nitrate and the lowest levels of ammonium. This is as expected since they were the sites with the coarser soil textures and the greatest separations to SHWT. Conversely, ammonium was the predominant form of nitrogen found at the RA site, with very little nitrate.

Figure 48 shows that of all four sites, the IP site had by far the highest mean total phosphorus levels. This can be attributed to the sandy soil that has a lower affinity for fixing phosphorus than finer textured soils.

Figure 49 compares the mean fecal coliform levels at all sites. The relatively high means for wells 1 and 4 at the IP site are somewhat skewed. This is due to a level of 80 MPN/100 ml measured in both wells at the first sampling event. Without this one measurement, the mean for both wells would be 1.3 MPN/100 ml. It is unclear as to why they measured so high at that one event, especially since the in-field well never detected coliforms. With that in mind, the RA site and the JI site had the highest mean coliform levels. As stated before, well 6 at the RA site did not appear to be influenced by the onsite system. Its fecal average is also skewed due to one erratic high measurement.

Overall Onsite System Performance

The separation distance between the trench bottoms and the SHWT at all sites by far exceeded the 6-inch minimum required by R.61-56, averaging 2 to almost 7 feet throughout the study period. Consequently, the impacts of having *only* a 6-inch separation distance could not be determined. In addition, the dryness of some of the downgradient wells precluded a complete analysis of the movement of the plume in some cases. However, the evaluation of the overall performance of the systems under existing conditions did provide interesting and valuable results.

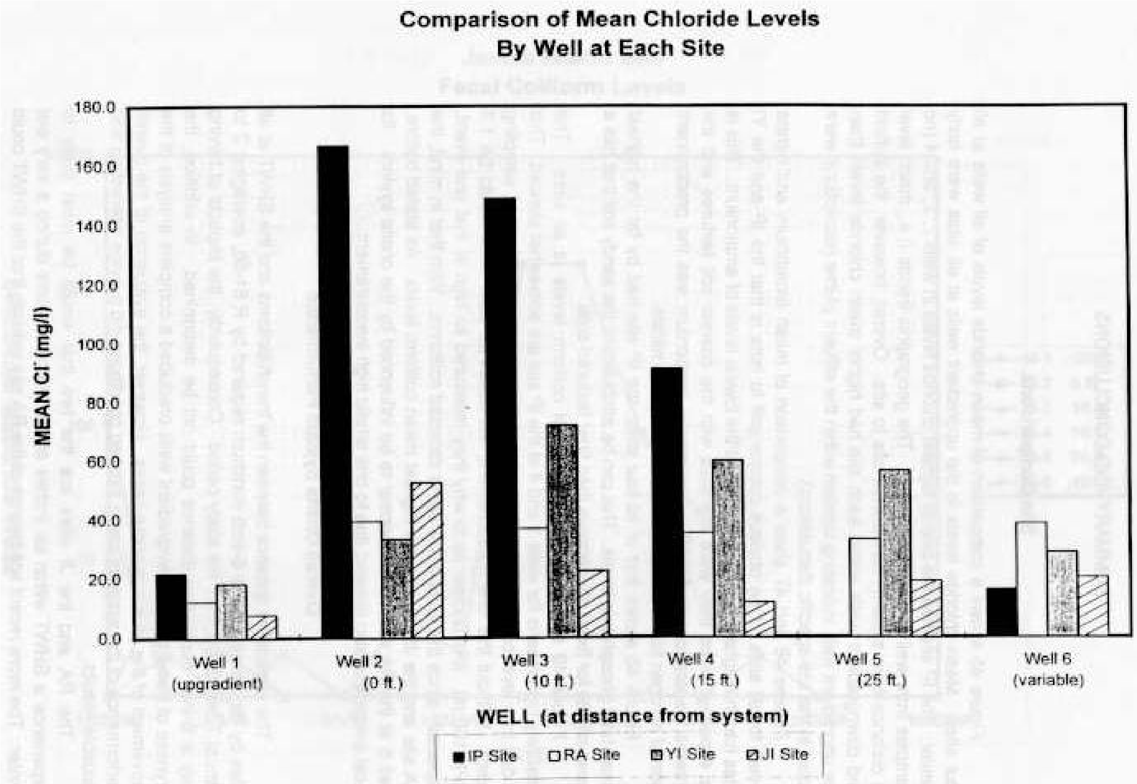


Figure 45. Mean chloride levels at each site.

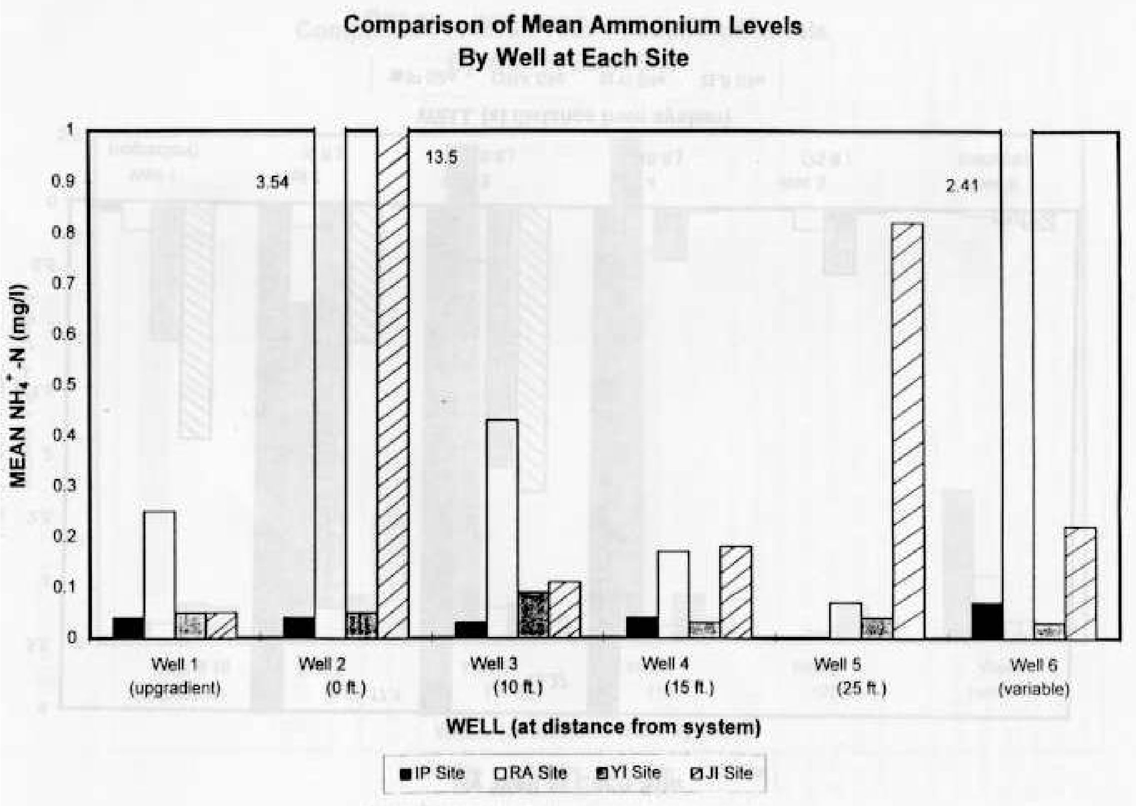


Figure 46. Mean ammonium levels at each site.

Comparison of Mean Nitrate Levels By Well at Each Site

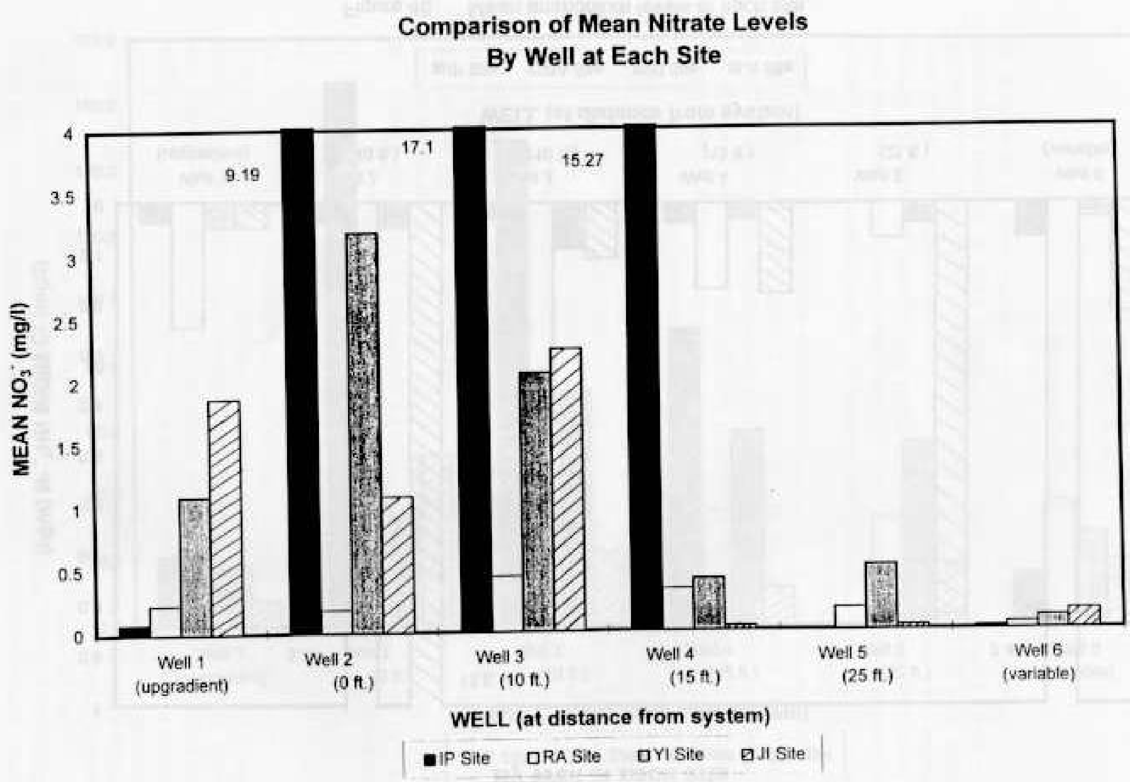


Figure 47. Mean nitrate levels at each site.

Comparison of Mean Total Phosphorus Levels By Well at Each Site

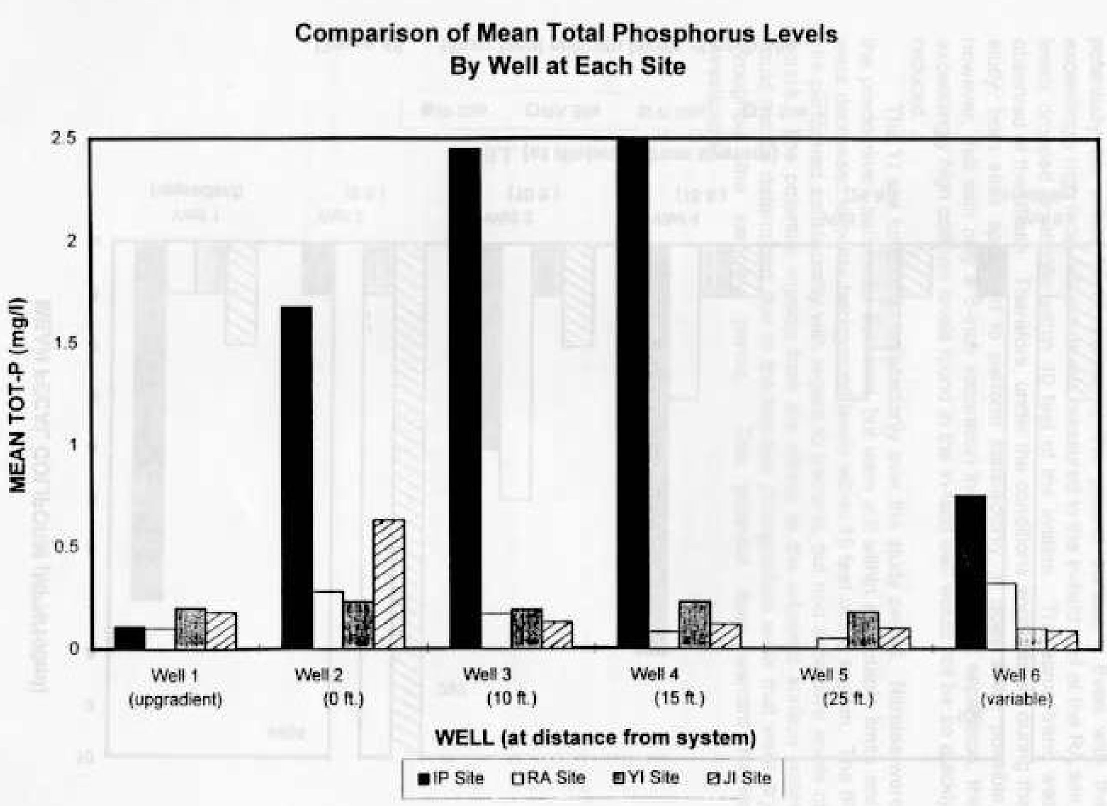


Figure 48. Mean total phosphorus levels at each site.

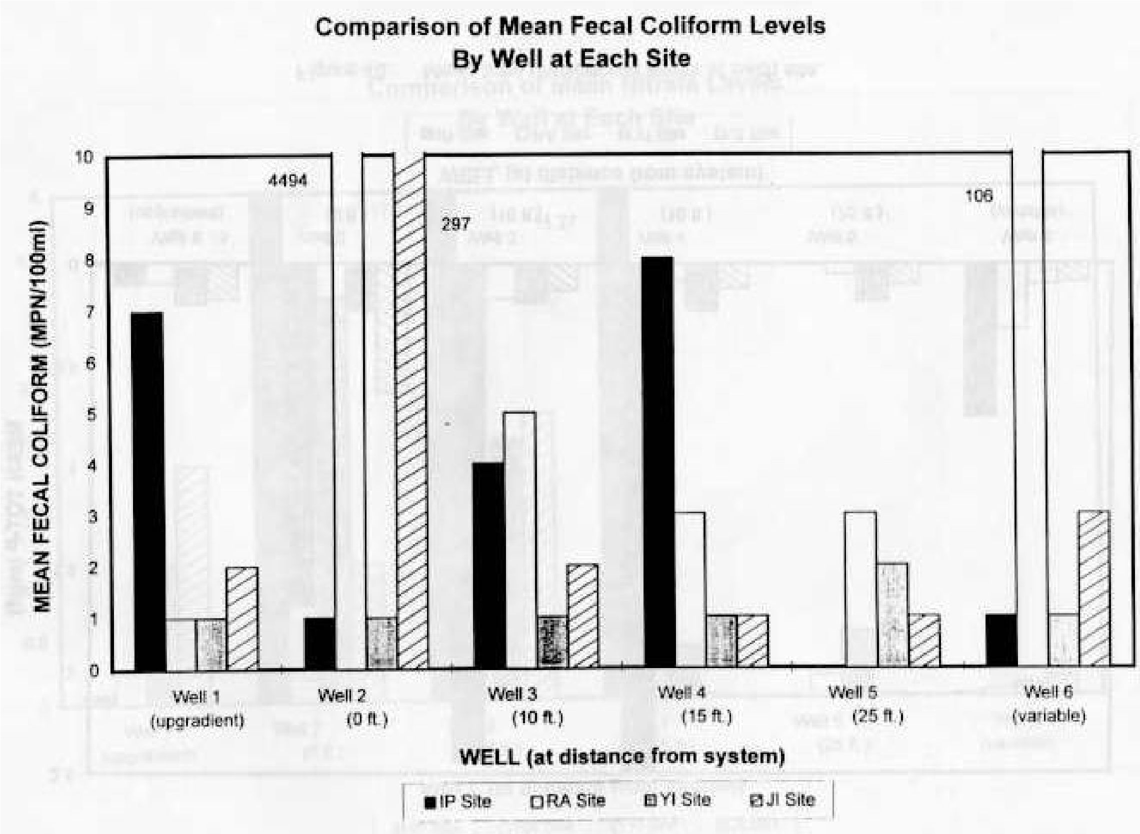


Figure 49. Mean fecal coliform levels at each site.

The RA and the JI sites are the two that would be most likely to experience a SHWT within six inches of the trench bottoms during a very wet winter. The more recent soil borings at the RA site indicate that the SHWT could potentially be within 10-12 inches of the ground surface. Even with the exceedingly high fecal coliform levels measured in the in-field well at the RA site, levels dropped drastically within 10 feet of the system. The same trend was observed at the JI site. Therefore, under the conditions encountered during the study, both sites appeared to perform satisfactorily. It does seem possible, however, that with only a 6-inch separation instead of a 4-foot separation, the exceedingly high coliform levels found in the in-field well would not be so quickly reduced.

The YI site functioned satisfactorily over the study period. Nitrates were the predominant parameter detected, but were still within acceptable limits and were decreased to below background levels within 15 feet of the system. The IP site performed satisfactorily with regard to bacteria, but had excessive levels of nitrate. The potential impacts from the nitrate to the adjacent surface water could not be determined due to the last two downgradient wells that were dry throughout the sampling period. This potential does warrant further investigation.

<u>REFERENCES CITED</u>

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APPENDIX A

ONSITE PERMITS

SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL
PERMIT TO CONSTRUCT—CERTIFICATE OF FINAL APPROVAL
INDIVIDUAL SEWAGE DISPOSAL SYSTEM

File Isle of Palm

Permit No. 301439-82 Date Issued 10-25-82
Name
Mailing Address Isle of Palms
Location Subdevelopment 'Isle of Palms TM# 568-11-00-016
Street Palm Blvd. Block B Lot

THIS PERMIT BECOMES VOID 12 MONTHS AFTER DATE OF ISSUE

SYSTEM SPECIFICATIONS

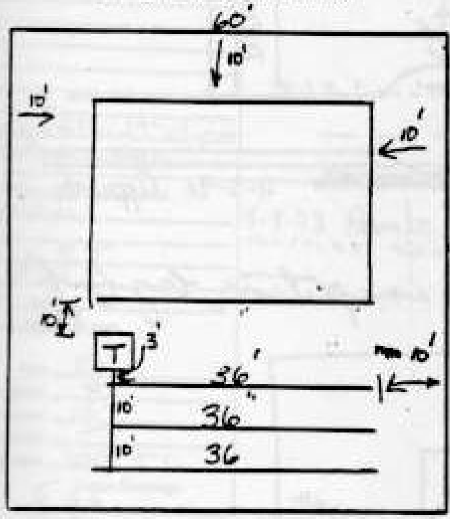
Sewage Disposal System Contractor
No. Bedrooms 3
Tank Size 1000 Gal
Trenches: Length 133 feet
Width 36 inches

Tank Manufacturer
Pipe Manufacturer(s)
Well Installed At Time Of Final Inspection ___ Yes ___ No
Actual Distance To: Well
Foundation
Property Line

Special Instructions install as sketched - conventional depth.

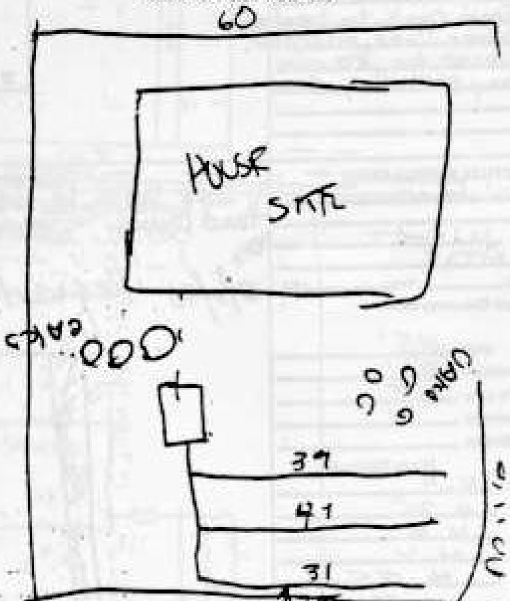
Make sketches illustrating: lot dimensions, if less than 2 acres; location of building; tank location; detailed layout of tile field; location of well; location of driveway; absorption trench elevations.

Sketch of Recommended Installation



Palm Blvd.

Sketch of Actual Installation



Permit Issued By: J.W. Cook
Date Issued: 10-26-82

Final Approval Given By: Harry Turner
Date Approved: 6-7-91

THIS CERTIFICATE OF FINAL APPROVAL IN NO WAY GUARANTEES THE LIFE OF THE SYSTEM OR THAT IT WILL FUNCTION PROPERLY UNDER ANY OR ALL CONDITIONS. NO ADDITIONAL CONNECTIONS TO THE ABOVE SYSTEM OR THE ADDITION OF OTHER SYSTEMS OF THE LOT WILL BE PERMITTED.

Onsite permit for IP site

SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL

PERMIT TO CONSTRUCT - CERTIFICATE OF FINAL APPROVAL
INDIVIDUAL SEWAGE TREATMENT AND DISPOSAL SYSTEM

Permit No 1102-88 Type Facility SFR 4Brs System Category 362-230

Name ______ Mailing Address ______ Ravenel, S.C. 29470

Subdevelopment St. Pauls Parish TMS 245-00-00-007 Street ______ Block ______ Lot ______ Type Water Supply private

SYSTEM SPECIFICATIONS

Max Est Daily Flow 480 gpd
Loading Rate .8 gpd/ft²
Tank Size(s) 1000 gallon

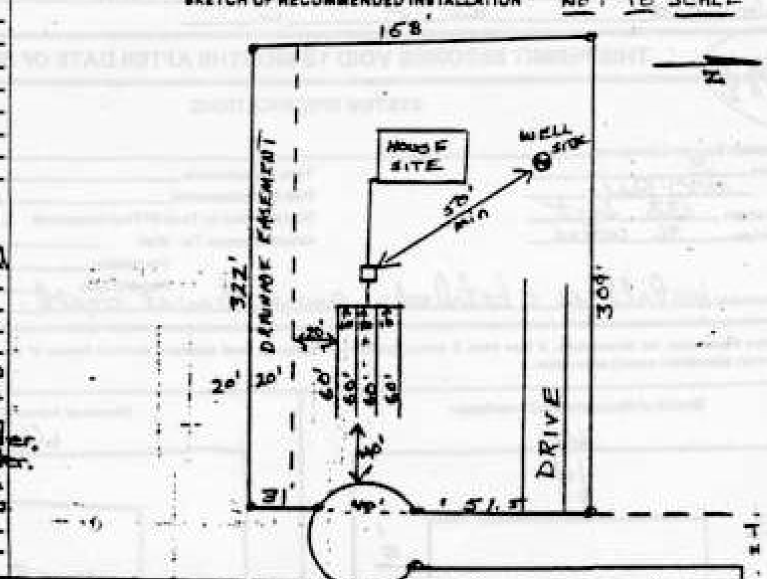
Trenches Length 270'
Width 36"
Max Depth 15"
Stone Depth 9"
Min Pump Capacity N/A gpm
at N/A ft. of Head

SPECIAL INSTRUCTIONS/CONDITIONS

Install in area flagged out, and per attachment.

Do not pack drive or build over system. Ensure plumbing stub out is compatible with trench depths. 3' solid line from tank to header, 10' between lines, on center. Well must be 50 min from any part of system.

SKETCH OF RECOMMENDED INSTALLATION NOT TO SCALE



ACTUAL INSTALLATION

Installer Wilson

Tank(s) Mfg. West
Pipe Mfg. ADS
Well Installed ____ Yes ____ No
Nearest Actual Distances from System to:

Well 85'
Foundation 20'
Property Line 45
Impoundment ______
Stream ______

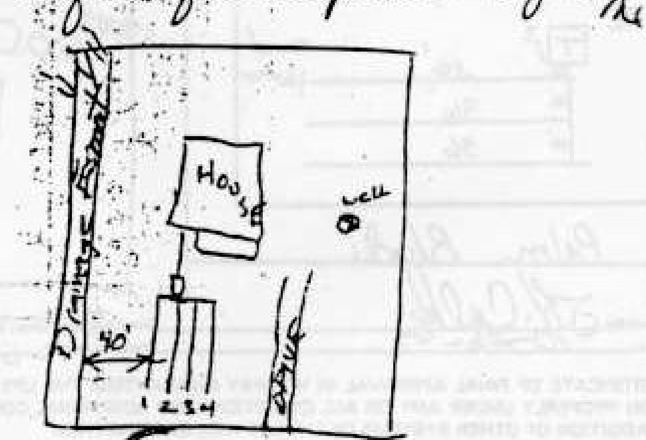
Line No.	Grade Readings
IN	4.4
OUT	4.75
1	4.5
2	4.4
3	4.45
4	4.5-5.5
TRENCH	14-17
ROCK	9-11"

SKETCH OF ACTUAL INSTALLATION

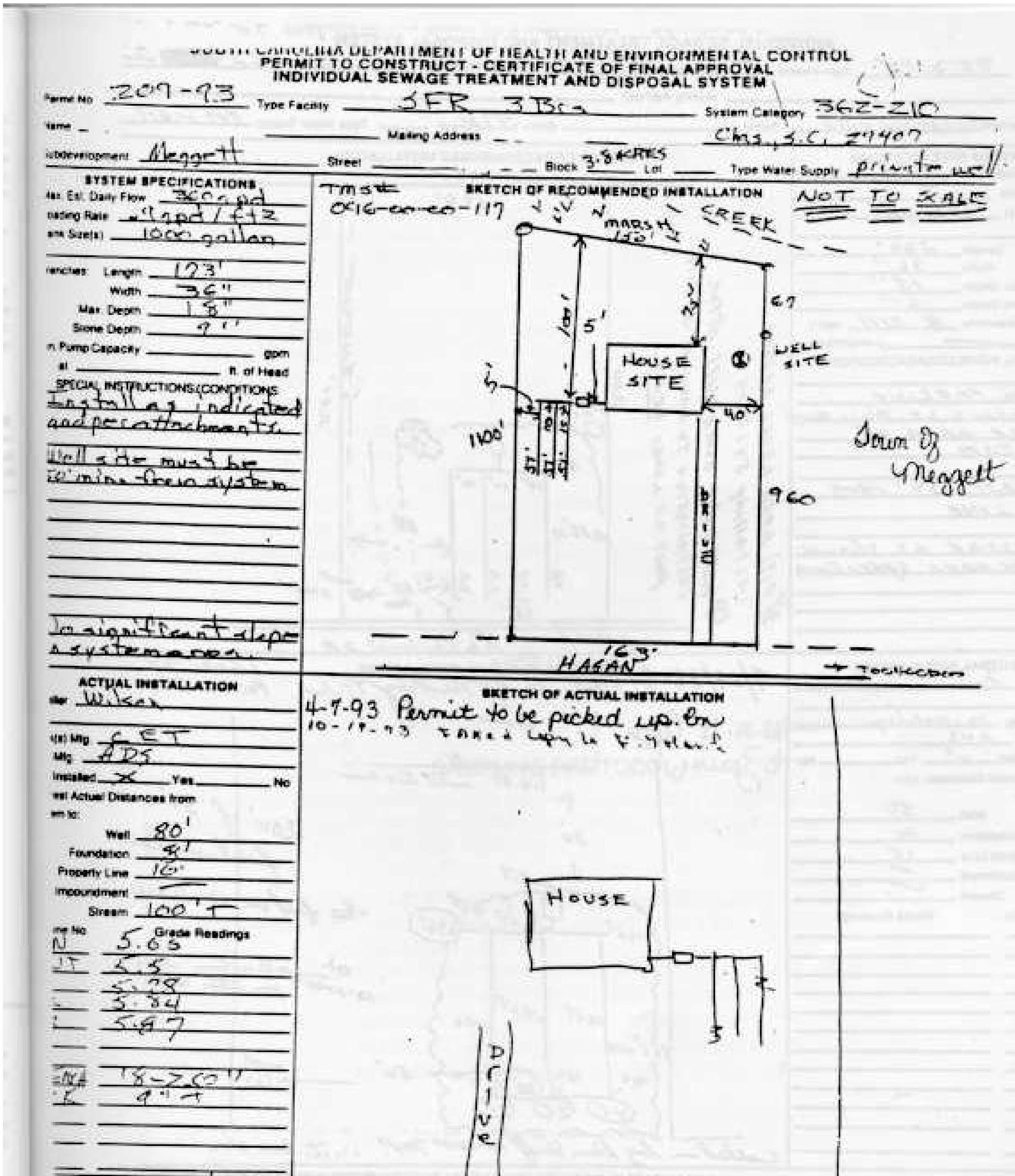
2-5-90 Appr. to

11-2-88 Copies to be hand carried to Zoning by

2/2/90 Request for inspection by A/ha



Onsite permit for RA site



SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL
PERMIT TO CONSTRUCT - CERTIFICATE OF FINAL APPROVAL
INDIVIDUAL SEWAGE TREATMENT AND DISPOSAL SYSTEM

Permit No. 207-93 Type Facility SFR 3 Br System Category 362-210
Name Mailing Address Chas., S.C. 29407
Subdevelopment Meggett Street Block 3.8 ACRES Lot Type Water Supply private well

SYSTEM SPECIFICATIONS
Max. Est. Daily Flow 360 gpd
Loading Rate .41 gpd / ft2
Tank Size(s) 1000 gallon
Trenches: Length 173'
Width 36"
Max. Depth 15"
Stone Depth 9"
Min. Pump Capacity gpm
at ft. of Head
SPECIAL INSTRUCTIONS/CONDITIONS
Install as indicated and per attachments.
Well site must be 50' min. from system
No significant slope in system area.

SKETCH OF RECOMMENDED INSTALLATION
TMS# 016-00-00-117
NOT TO SCALE
MARSH
CREEK
150'
67
32'
100'
5'
HOUSE SITE
WELL SITE
40'
5'
1100'
960
DRIVE
163'
HAGAN
→ TOOKEDAH
Town of Meggett

ACTUAL INSTALLATION
Installer Wilson
Tank(s) Mfg. CET
Mfg. ADS
Installed X Yes No
Actual Distances from System to:
Well 80'
Foundation 8'
Property Line 16'
Impoundment —
Stream 100'+

Line No.	Grade Readings
N	5.65
JT	5.5
	5.78
	5.84
	5.97
AVG	18-20"
	9"

SKETCH OF ACTUAL INSTALLATION
4-7-93 Permit to be picked up. Bm
10-19-93 TAKEN UP ...
HOUSE
3
DRIVE

Onsite permit for YI site

INDIVIDUAL SEWAGE TREATMENT AND DISPOSAL SYSTEM

Permit No. 753-88 Type Facility RESIDENTIAL - 3 BEDROOM System Category 3C [redacted] 2

Name ______ Mailing Address ______

Subdevelopment Secession Ville Street ______ Block 47AC Lot ______ Type Water Supply PVT WELL

SYSTEM SPECIFICATIONS

Max. Est. Daily Flow 360

Loading Rate .8

Tank Size(s) 1000 gal

Trenches Length 200'

Width 36"

Max. Depth 15"

Stone Depth 6"

~~Min. Pump Capacity~~ * Fill gpm

at ______ ft of head

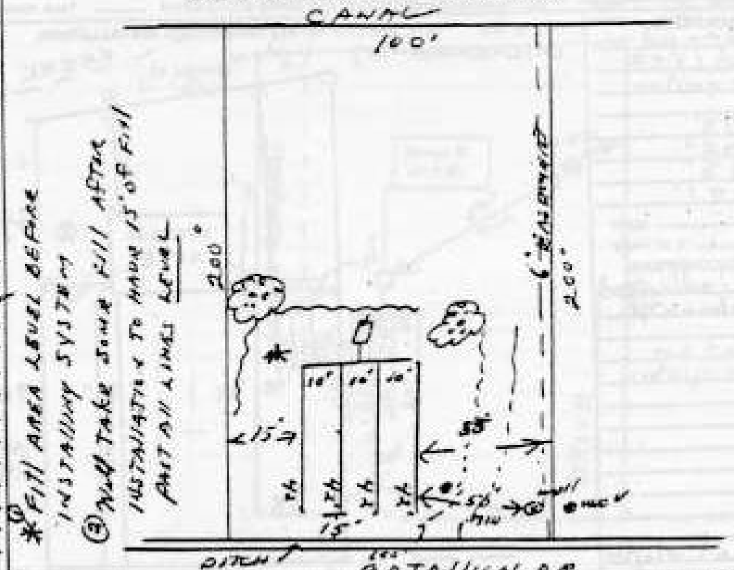
SPECIAL INSTRUCTIONS/CONDITIONS

(1) NO PARKING, DRIVING OR BUILDING OVER AREA OF SYSTEM

(2) WELL 50' FROM ANY LINE

(3) INSTALL AS SHOWN AN IN AREA SPECIFIED

SKETCH OF RECOMMENDED INSTALLATION



ACTUAL INSTALLATION

Installer Lamin

Tank(s) Mfg. ______

Pipe Mfg. ADS

Well Installed ✓ Yes ______ No ______

Nearest Actual Distances from System to

Well 50

Foundation 30

Property Line 15

Impoundment —

Stream —

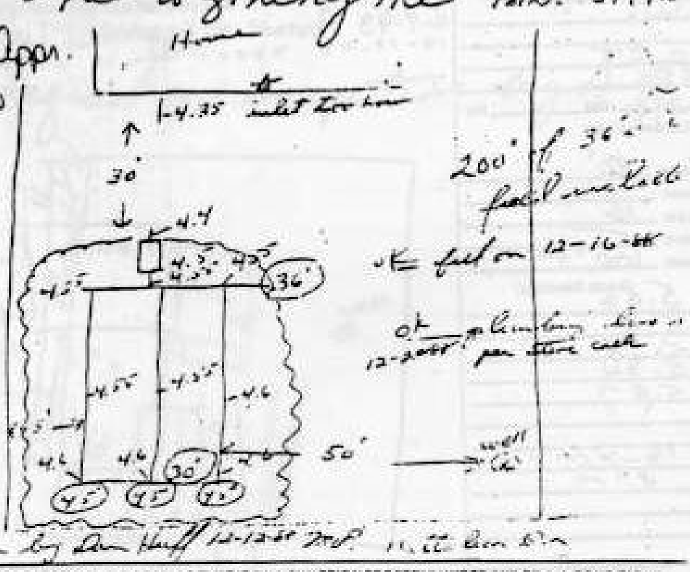
Line No.	Grade Readings

SKETCH OF ACTUAL INSTALLATION

7/29/88 Copie to Zoning me

12-21-88 Appr. to Zoning

12-12-88 Feins. St. In



THIS CERTIFICATE OF FINAL APPROVAL IN NO WAY GUARANTEES THE LIFE OF THE SYSTEM OR THAT IT WILL FUNCTION PROPERLY UNDER ANY OR ALL CONDITIONS

Onsite permit for JI site

APPENDIX B

SAMPLING PROTOCOL

.

SAMPLING PROTOCOL

General Order of Events for Sampling

1. Calibrate pH and conductivity meters
2. Load truck with sampling equipment and supplies (see checklist)
3. Drive to site
4. Measure static water levels in wells
5. Do well volume calculations and record on field data sheets
6. Sample wells
7. Gather equipment
8. Drive to Trident EQC lab
9. Give fecal samples to bacterial lab technician
10. Acidify nitrate & ammonium samples in chemical lab
11. Log samples into EQC log book
12. Label chemical samples with assigned numbers from EQC log book
13. Wash and prep bailers
14. Collect materials needed for next sampling event

Calibration of Meters

Points to remember:

- Meters are calibrated each morning before a sampling event.
- Buffer solutions should be at room temperature
- The pH meter is an Oakton pHtestr3 with a resolution of 0.01 and +/- 0.02 pH accuracy. Follow manufacturer's calibration directions using buffer solutions pH4, pH7, and pH10.
- The conductivity meter is an Oakton TDSTester10 & 20 and has a +/- 2% accuracy. Follow manufacturer's calibration directions using standards that bracket the expected values of the groundwater. The available standards include 147, 432, 1409, and 1417 μmho/cm.

Water Level Reading and Well Sampling Order

The well order listed below is to be followed each time at each site:

1. Well 1 - Upgradient from system
2. Well 6 - Downgradient from system (furthest away)
3. Well 5 - approx. 15 feet from system (downgradient)
4. Well 4 - approx. 10 feet from system (downgradient)
5. Well 3 - approx. 5 feet from system (downgradient)
6. Well 2 - between trenches in the absorption field

Water Level Readings

The first step in collecting groundwater samples is to determine the depth to groundwater (DGW) in each monitoring well. The following procedure is followed at each well at each site:

1. Place the following supplies in the 2-gallon plastic pail which will be carried to each well: spray bottle with deionized (DI) water, the water level indicator, keys for well locks, the orange data book and pencil. The water level indicator consists of the light meter attached to the 100-foot fiberglass measuring tape.
2. Put on disposable gloves. These are to be worn at all times.
3. Remove well box cover and place inverted on ground near well.
4. Unlock well cap lock and place lock inside well box cover.
5. Remove well cap and place inside well box cover.
6. Insert water level indicator slowly into well until the meter illuminates.
7. Bob the meter a few times in order to obtain an accurate water level.
8. Read the tape measurement to the nearest 0.01 ft. at the reference point on the casing top.
9. Record measurement to the nearest 0.01 ft in the orange data book, adding 0.92 to reading to account for light meter length.
10. While removing the water level indicator, rinse with DI water from spray bottle.
11. Replace the well cap without locking.
12. Place inverted well box cover over well opening to keep out debris.
13. Repeat procedure at remaining wells.
14. If only measuring DGW, return to all wells and securely lock caps and replace well box covers. If sampling wells, continue with calculations and sampling procedure below.

Calculations For Determining Well Volume

Once depth to groundwater (DGW) is determined, the following should be calculated and recorded on the Field Data Sheets* prior to beginning well sampling procedure:

1. Determine Length of Water Column (LWC) to nearest 0.01 ft.:
   (LWC) = (TWD)** - (DGW)
2. Determine one well casing volume (OCV) in gallons:
   (OCV) = (LWC) X (0.163)
3. Determine three well casing volumes (standard evacuation volume) in gallons:
   standard evacuation volume = (OCV) x 3

* See attached Field Data Sheet for example
** TWD = total well depth

Well Sampling

After recording water levels and calculating well volumes, sampling may begin. To collect groundwater samples, wells must first be purged to remove stagnant well water. This ensures that the collected samples are representative of the groundwater in the vicinity of the well.

1. Put on a new pair of disposable gloves.

2. Using a Teflon bailer with pre-cut twine*, bail out one well volume and pour into a calibrated bucket. After one well volume, fill a 100 ml beaker with groundwater and measure pH, specific conductance, and temperature (field indicator parameters). Record measurements on field data sheet.**
3. Purge a second and third well volume, recording indicator parameter measurements. Typically, three well volumes are purged during stabilization. Purging will continue however if any of the indicator parameters vary by more than 15%.
4. Sampling begins once all field indicator parameters are stabilized.
5. The first sample is collected for dissolved oxygen (DO). Allow enough time, if possible, for the well to recharge sufficiently to fill the bailer. Note the condition of the well, the relative recharge rate, and the total volume of water purged from the well on the Field Data Sheet.
6. Collect one bailer volume and insert bottom flow sampling tip. The sampling tip ensures a slow, even stream and minimizes the introduction of oxygen into the sample.
7. The DO bottle is tilted at a slight angle and the sample tip is inserted and opened for flow. Continue until the bottle is full and allowed to overflow significantly. Withdraw the sample tip slowly while sample is still flowing. Insert the glass stopper into the DO bottle and close the sampling tip. Carefully place the bottle in the sample carrier.
8. If sufficient volume of sample remains in the bailer, fill the chloride sample bottle and then remove the sampling tip.
9. Continue to collect groundwater with the bailer, and pour into chloride, nutrient, and fecal coliform sample bottles using the v-notched top of the bailer.
10. Carry all sample bottles to the vehicle and, with the exception of the DO bottle, place securely in the cooler.
11. Perform the DO procedure (using Hach Dissolved Oxygen Test Kit Model OX-2P) according to the manufacturers directions & place DO bottle in secure area.
12. Return to the sampled well and lock the cap and replace valve box cover.
13. Put on a new pair of disposable gloves before sampling next well.

*Note: There should be one cleaned bailer per well (see section below). The bailer twine is wound around the gloved hand in a manner that does not allow the twine to ever touch the ground.

**If recharge is very slow:

1. Bail dry (measure field indicator parameters on last bailer) and allow to recharge.
2. Collect as many samples as possible and allow to recharge. Continue this procedure until all samples are taken as time will allow. Measure field indicator parameters on last bailer.

Washing and Preparing Bailers

We have a total of six bailers which allows for a bailer for each well per sampling event (there is no bailer cleaning in the field, unless an accident occurs). The bailers consist of Norwell mix & match bailer components made of 100% virgin Teflon Fluoropolymer resin. Each bailer has 6 separate pieces: a v-notched top, a one-foot bailer body, and a 3-piece “controlled flow bottom-emptying assembly” which includes a sample valve that can be inserted at sample time. Disposable bailers are used for well W-6 at the Ravenel site.To wash, disconnect all pieces and place in sink of hot water and Liquinox soap. Allow to sit for a few minutes to loosen any sand that may have entered the bailer during the sampling process.

1. Begin with the bailer body, scrub inside and out with a stiff bottle brush. Then scrub tops, bottoms and sample tips.
2. Rinse each piece three times with tap water and set aside on a clean plastic bag.
3. Rinse sampling tips again 3 times with DI water, reassemble and place each tip in a separate, new, resealable plastic sandwich bag.
4. Take tap-rinsed bailer bodies, tops, and bottoms to the DI sink. Rinse each part 3 times with DI water and assemble one set at a time. Set aside on clean plastic bag. Continue with each bailer.
5. Tie an appropriate length (based on total well depth) of nylon sampling twine to each bailer and place each bailer in a separate, clean plastic bag and seal. Once all are complete, place them in the plastic tub and close lid.
6. Load vehicle with equipment, DI & tap water (if needed) and sampling bottles for the next sampling event.

Calibration Steps for pH and Conductivity Meters

pH meter

1. Rinse 3 beakers with deionized (DI) water and shake out excess water.
2. Prepare dedicated beakers with one inch of buffer solution starting with pH 7, the second beaker with buffer pH 4, and the third beaker with buffer pH 10.
3. Remove cap and rinse pH meter probe with DI water.
4. Insert probe in buffer solution pH 7, carefully so as not to immerse over the color band. Once in solution, turn the meter on and press the “CAL” button for calibration mode. Swirl the meter and wait for the display to stabilize. Once stabilized, press the “HOLD/CON” button to confirm & complete the calibration.
5. Remove and rinse the probe with DI water and repeat steps for buffer 4 and buffer 10, in that order.
6. After all calibrations, rinse probe with DI water, turn off and replace cap.

Conductivity Meter

1. Prepare dedicated beakers each with approximately one inch of solution. There are two beakers per solution. It is best to select calibration standards that bracket the expected values of the groundwater. The available standards include 147, 432, 1409, and 1417 μmho/cm.
2. Remove cap and rinse conductivity meter probe with DI water.
3. Insert probe into first beaker of solution 1; swirl, remove and place meter in second beaker of solution 1.
4. Turn the meter on once it is placed in the second beaker of solution 1 and allow the display to stabilize.
5. Once stabilized, press “CAL/CON” button for the calibration mode.

6. Press “HOLD/INC” to move value up/down so that the display shows the value of the standard.
7. Press “CAL/CON” button again. Observe “CO” on the display, confirming calibration into memory.
8. Rinse probe with DI water & check first beaker of solution 1 to verify the calibrated value.
9. Repeat same procedure with other selected standard solution.
10. After all calibrations, rinse probe with DI water, turn off and replace cap.

APPENDIX C

RAW DATA

For copies of these appendices, please contact the SC-DHEC Office of Ocean & Coastal Management, 1362 McMillan Avenue, Suite 400, Charleston, SC 29405.

APPENDIX D

SOIL BORING LOGS

SOIL BORING LOG

SITE: Isle of Palms Site
DATE: November 7, 1995
WEATHER CONDITIONS: partly cloudy, humid, 70's
BORING LOCATION: Boring #1 - by well CB-1
Boring #2 - by well CB-2
Boring #3 - by well CB-6
BORING BY: Steve Calk
ADDITIONAL INFORMATION: The auger used is only 48 inches long, therefore the profile descriptions do not go as deep as the wells.

BORING NO.	DEPTH (in.)	TEXTURE	MATRIX COLOR	MOTTLES/WATER
1	0-3	CBS	10YR 4/3 brown	
	3-24	CBS	10YR 8/6 yellow (washed)	
	24-47	CBS	10YR 5/4 yellowish brown	SHWT > 36 in.
2	0-20	CBS	10YR 5/4 yellowish brown	
	20-33	CBS	10YR 6/3 pale brown	
	33-40	OSL	10YR 3/1 very dark gray	SHWT > 36 in.
	40+	CBS	10YR 6/3 pale brown	
3	0-15	CBS	10YR 5/4 yellowish brown	
	15-18	CBS	10YR 4/4 dark yellowish brown	
	18-47	CBS	10YR 6/4 light yellowish brown	SHWT > 36 in.

CBS = coastal beach sand
OSL = organic sandy loam
SHWT = seasonal high water table

SOIL BORING LOG

SITE: Ravenel Site
DATE: July 22, 1996
WEATHER CONDITIONS: cloudy, hot, humid
BORING LOCATION: 10 feet from well W-2, between 2 trenches, toward road
BORING BY: Steve Calk & Lisa Hajjar
ADDITIONAL INFORMATION: Due to strong septage smell and no protective gloves, boring was ceased at 72+ inches.

BORING NO.	DEPTH (in.)	TEXTURE	MATRIX COLOR	MOTTLES/WATER
1	0-4	fill		
	4-6	sl	5YR 3/1 very dark gray	
	6-12	sl	10YR 5/3 brown	9-10" few, faint mottles SHWT at 12 in.
	12-18	scl	7.5YR 6/6 reddish yellow	
	18-22	cl	7.5YR 5/6 strong brown	
	22-34	cl	7.5YR 5/6 strong brown	abundant mottles
	34-50	cl	5YR 5/8 yellowish red	abundant mottles
	50-72	sl - scl	5YR 6/8 reddish yellow	10YR 7/1 light gray (very mottled)
	72+	sl	(variable) 10G 2.5/1 greenish black	apparent water table

sl = sandy loam
scl = sandy clay loam
cl = clay loam
SHWT = seasonal high water table

SOIL BORING LOG

SITE: Ravenel Site
DATE: August 6, 1996

WEATHER CONDITIONS: cloudy, hot, humid
BORING LOCATION: 3 feet from well W-1
BORING BY: Steve Calk & Lisa Hajjar
ADDITIONAL INFORMATION:

BORING NO.	DEPTH (in.)	TEXTURE	MATRIX COLOR	MOTTLES/WATER
2	0-3.5	sl	2.5Y 3/2 very dark grayish brown	
	3.5-10	scl	10YR 5/8 yellowish brown	10YR 7/1 light gray at 10" common, medium, distinct SHWT at 10+ in.
	10-17	cl	10YR 5/8 yellowish brown	
	17-27	cl	10YR 5/8 yellowish brown	light gray mottles & iron concretions
	27-40	sc	10YR 5/8 yellowish brown	
	40-42	scl	7.5YR 5/8 strong brown	
	42-46	sc	no predominant matrix color	
	46-57	scl	no predominant matrix color	
	57-61	cl	10YR 7/1 light gray	reddish yellow
	61-63	cl	7.5YR 5/8 strong brown	
	63-69	sl	10YR 6/4 very pale brown	
	69-73	s	10YR 7/1 light gray	
	73-86	s	2.5Y 7/4 pale yellow	reddish yellow & light gray / observable water
	86+	s	2.5Y 7/2 light gray	light gray / apparent water table at 88 in.

sl = sandy loam
scl = sandy clay loam
sc = sandy clay
cl = clay loam
s = sand
SHWT = seasonal high water table

SOIL BORING LOG

SITE: Ravenel Site
DATE: August 6, 1996
WEATHER CONDITIONS: cloudy, hot, humid
BORING LOCATION: between wells W-5 and W-4
BORING BY: Steve Calk & Lisa Hajjar
ADDITIONAL INFORMATION: Indication of disturbed soils; could be spoils from ditch.

BORING NO.	DEPTH (in.)	TEXTURE	MATRIX COLOR	MOTTLES/WATER
3	0-5	sl	10YR 2/2 very dark brown	
	5-34	scl	very mixed / fill	very mottled / fill SHWT hard to call
	34-40	scl	5YR 5/8 yellowish red	10R 5/8 red
	40-66	scl	7.5 YR 5/6 strong brown	2.5Y 7/1 light gray 1 in^3 piece of slag found at 48 in.
	66-73	cl	2.5Y 7/1 light gray	7.5 YR 5/6 strong brown 10YR 7/8 yellow
	73-77	c	2.5Y 7/1 light gray	7.5 YR 5/6 strong brown 10YR 7/8 yellow
	77-108	scl	2.5Y 7/1 light gray	7.5 YR 5/6 strong brown 10YR 7/8 yellow
	108+	scl	7.5YR 5/8 strong brown	2.5Y 7/1 light gray

sl = sandy loam
scl = sandy clay loam
cl = clay loam
c = clay
SHWT = seasonal high water table

SOIL BORING LOG

SITE: Ravenel Site
DATE: August 6, 1996

WEATHER CONDITIONS: light rain, hot
BORING LOCATION: 2.5 feet from well W-6
BORING BY: Steve Calk & Lisa Hajjar
ADDITIONAL INFORMATION:

BORING NO.	DEPTH (in.)	TEXTURE	MATRIX COLOR	MOTTLES/WATER
4	0-2	sl	(did not note)	
	2-12	sl	10YR 3/2 very dark grayish brown	
	12-15	scl	5YR 5/6 yellowish red	
	15-30	scl	10YR 4/1 dark gray SHWT (?)	
	30-35	scl	10Y 4/1 dark greenish gray (may be orginal surface)	10BG 8/1 light greenish gray
	35-41	sl	5YR 2.5/1 black	
	41-46	s	10YR 3/1 very dark gray	
	46+	s	2.5Y 7/1 light gray	free water

sl = sandy loam
scl = sandy clay loam
s = sand
SHWT = seasonal high water table

SOIL BORING LOG

SITE: Yonges Island Site
DATE: August 6, 1996

WEATHER CONDITIONS: light rain
BORING LOCATION: 2.5 feet from well N-2
BORING BY: Steve Calk & Lisa Hajjar
ADDITIONAL INFORMATION:

BORING NO.	DEPTH (in.)	TEXTURE	MATRIX COLOR	MOTTLES/WATER
1	0-12	sl	10YR 3/2 very dark grayish brown	
	12-21	sl	2.5Y 5/4 light olive brown	
	21-32	sl	2.5Y 6/3 light yellowish brown	
	32-36	sl	2.5Y 7/4 pale yellow	
	36-40	sl	2.5Y 7/4 pale yellow	7.5YR 7/1 light gray SHWT at 36 in.
	40-48	sl	2.5Y 7/4 pale yellow	7.5YR 7/1 light gray 7.5 YR 6/8 reddish yellow
	48-56	ls	2.5Y 7/4 pale yellow	2.5Y 8/2 pale yellow
	56-62	ls	2.5Y 7/1 light gray	
	62-70	ls	2.5Y 6/4 light yellowish brown	7.5YR 7/1 light gray 7.5 YR 6/8 reddish yellow
	70-80	scl	2.5Y 7/1 light gray	2.5YR 4/8 red 7.5 YR 7/8 reddish yellow
	80-86	sl	2.5Y 7/1 light gray	2.5YR 4/8 (even mix with matrix)
	86-91	cl	2.5Y 7/1 light gray	2.5YR 4/8 (matrix dominates)
	91-95	sl	2.5Y 6/4 light yellowish brown	
	95-97	sl	2.5Y 7/1 light gray	10YR 7/8 yellow
	97+	scl	2.5Y 7/1 light gray	

sl = sandy loam
ls = loamy sand
scl = sandy clay loam
cl = clay loam
SHWT = seasonal high water table

SOIL BORING LOG

SITE: Yonges Island Site
DATE: June 26, 1996
WEATHER CONDITIONS: mostly cloudy, breezy, warm and humid
BORING LOCATION: approx. 2 feet behind well N-2 (away from water)
BORING BY: Lisa Hajjar
ADDITIONAL INFORMATION:

BORING NO.	DEPTH (in.)	TEXTURE	MATRIX COLOR	MOTTLES/WATER
1-a	0-5	sl	10 YR 5/3 brown	
	5-12	sl	10YR 4/3 brown	
	12-16	sl	10YR 5/4 yellowish brown	
	16-24	sl	2.5Y 6/3 light yellowish brown	10YR 2/1 black
	24-34	sl	10YR 5/6 yellowish brown	
	34-38	scl	10YR 5/6 yellowish brown	2.5Y 8/2 pale yellow (few, fine, faint) SHWT at 34"
	38-42	scl	10YR 6/6 brownish yellow	2.5Y 8/2 pale yellow (common, medium, distinct)
	42-50	scl	10YR 6/6 brownish yellow	2.5Y 8/2 pale yellow (many, coarse, prominent)
	50-54	scl	5YR 5/8 yellowish red	10YR 6/2 light brownish gray (many, coarse, prominent)
	54-58	sl	5YR 5/8 yellowish red	
	58-62	scl	5YR 5/8 yellowish red	
	62-64	sc	5YR 5/8 yellowish red	
	64-	scl	5YR 5/8 yellowish red	

sl = sandy loam
scl = sandy clay loam
SHWT = seasonal high water table

SOIL BORING LOG

SITE: James Island Site

DATE: July 9, 1986

WEATHER CONDITIONS: dry

BORING LOCATIONS: Boring #1: 25 feet from ditch toward house and 40 feet from property line opposite driveway. Boring #2: 50 feet from ditch and about 50 feet from property line by driveway. Boring #3: 75 feet from creek and 60 feet from property line by driveway.

BORING BY: Bill Britt (Chas. Co. Health Dept.)

ADDITIONAL INFORMATION: Borings were done in 1986, when lot was being re-evaluated for septic system (permit was originally issued in 1979 and had to be honored due to grandfather clause). Original data did not include Munsell color notations, only color names.

BORING NO.	DEPTH (in.)	TEXTURE	MATRIX COLOR	MOTTLES/WATER
1	0-16	ls	grayish brown	fill material
	16-27	sl	very dark grayish brown	shells mixed in
	27-36	sl	washed gray	
2	0-12	fls	brown	
	12-21	ls	yellow, red, & brown	gray & red mottles (fill)
	21-29	ols	dark gray	original soil
	29-36	ls	pale gray, brown	bleached out (soil wet)
3	0-6	fls	brown	
	6-16	ls & c	brown, red, gray & shells	soil mixed w/ shell & marl (fill)
	16-26	mixed texture	red, yellow, gray & brown	fill material
	26-30	ols	black	original soil (wet & organic)

ls = loamy sand
sl = sandy loam
fls = fine loamy sand
ols = organic loamy sand (textural class used by the Health Department)
SHWT = seasonal high water table